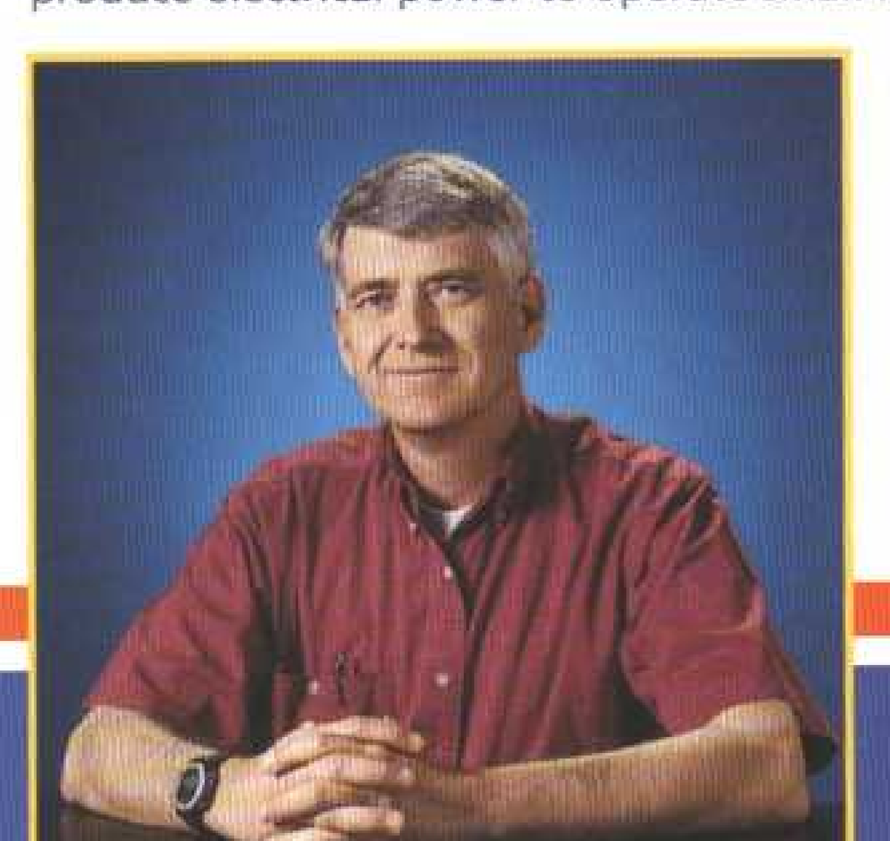
Solar cells have the remarkable ability to convert sunlight directly into electrical energy. They do so without producing pollution or noise. And they last many years.

This Mini-Notebook explains how you can use arrays of solar cells to produce electrical power to operate small motors, electronic circuits and other projects. It also shows how you can use solar cells to charge storage batteries. This means you can store the power of sunlight during the day and use it to power your projects at night. Solar cells also make great light sensors. This Mini-Notebook shows how to use solar cells to trigger relays, measure light, control tones and detect objects.



Forrest M. Mims III

Forrest M. Mims III has written dozens of books for RadioShack. He personally builds every circuit in his best-selling Engineer's Mini-Notebook series. He then uses a 0.7mm mechanical pencil to create pages for the finished book.

Building tiny instruments for model rockets, travel aids for the blind and high-power lasers is how Forrest got his start in electronics. When he's not writing RadioShack books, he writes magazine articles and teaches experimental science at the University of the Nations in Hawaii.

Forrest also does scientific studies of sunlight, the atmosphere, mosquitoes and bacteria using instruments he designs and makes. A simple instrument he developed to measure the ozone layer earned him a prestigious Rolex Award. NASA has sent Forrest and his instruments to several of the Western States and twice to Brazil to measure the effects of smoke from giant fires.

Forrest is a member of the Institute of Electrical and Electronics Engineers, the National Science Teachers Association and several scientific societies. He lives in Texas with his wife Minnie and their youngest daughter Sarah.



Printed In USA

ENGINEER'S Mini Notebook

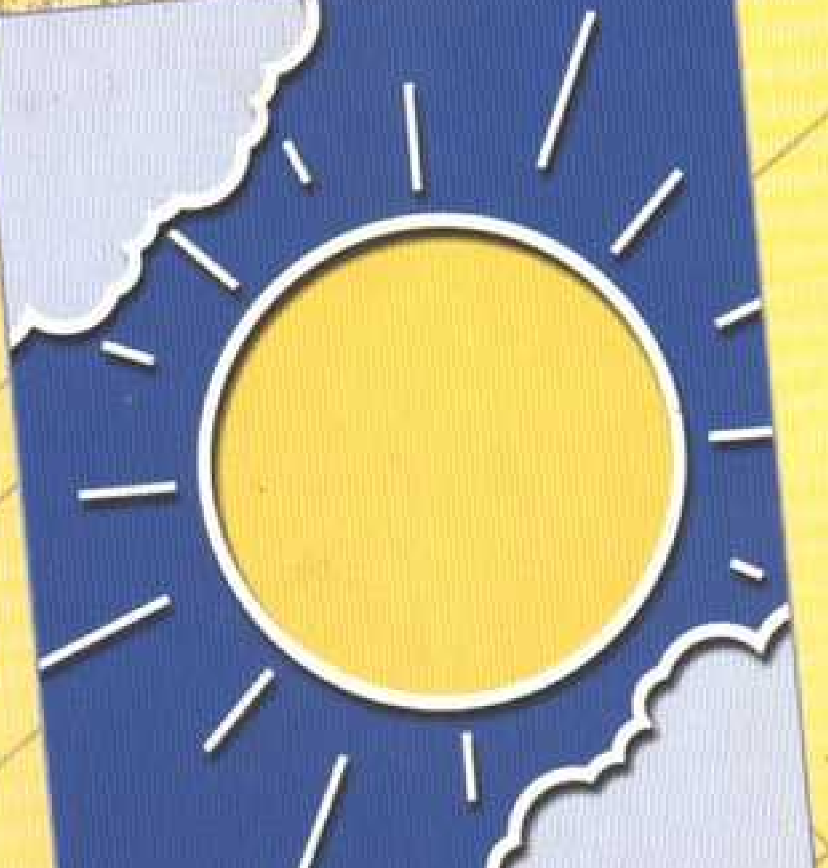
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RadioShack

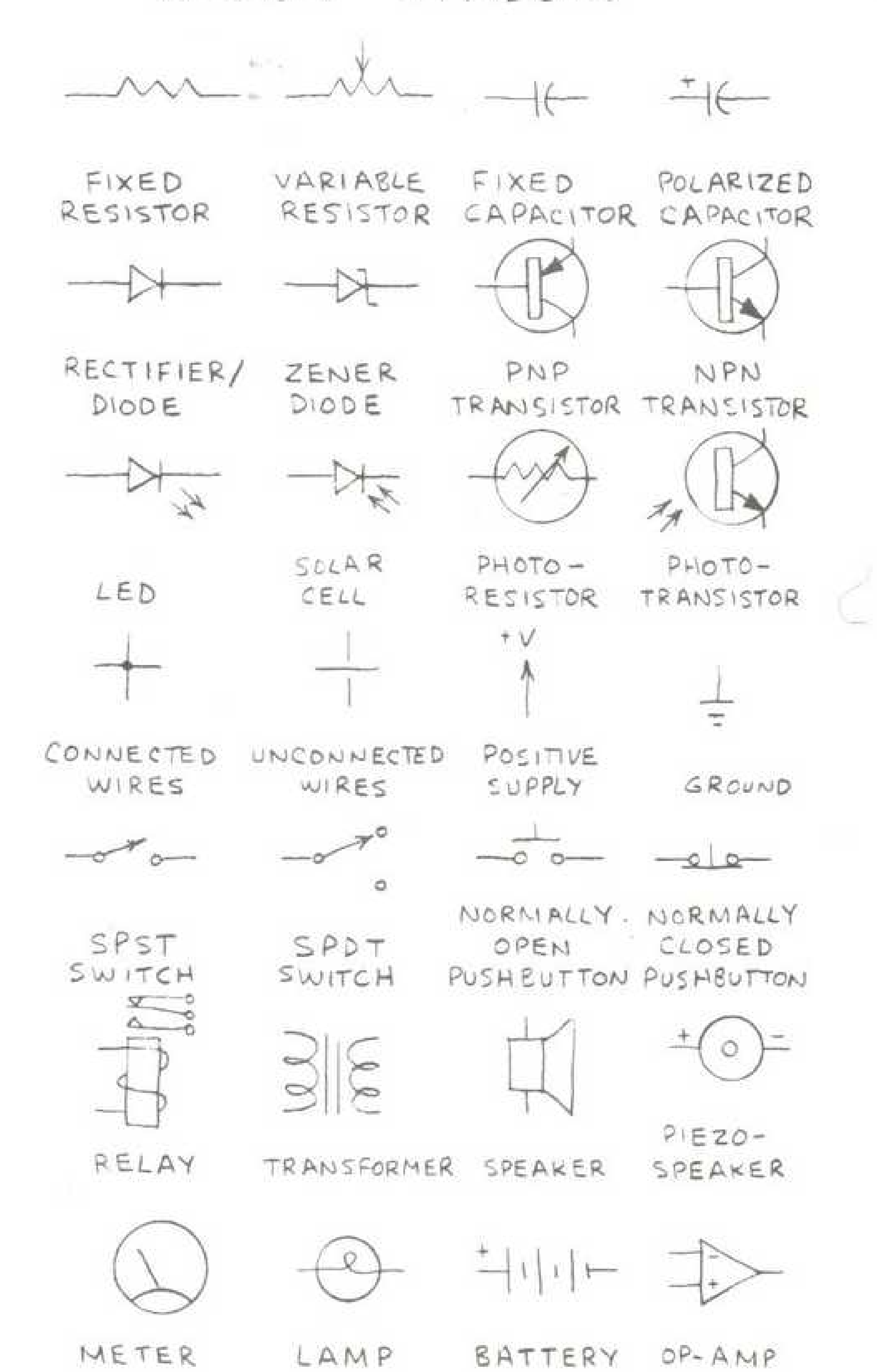
Solar Cell Projects

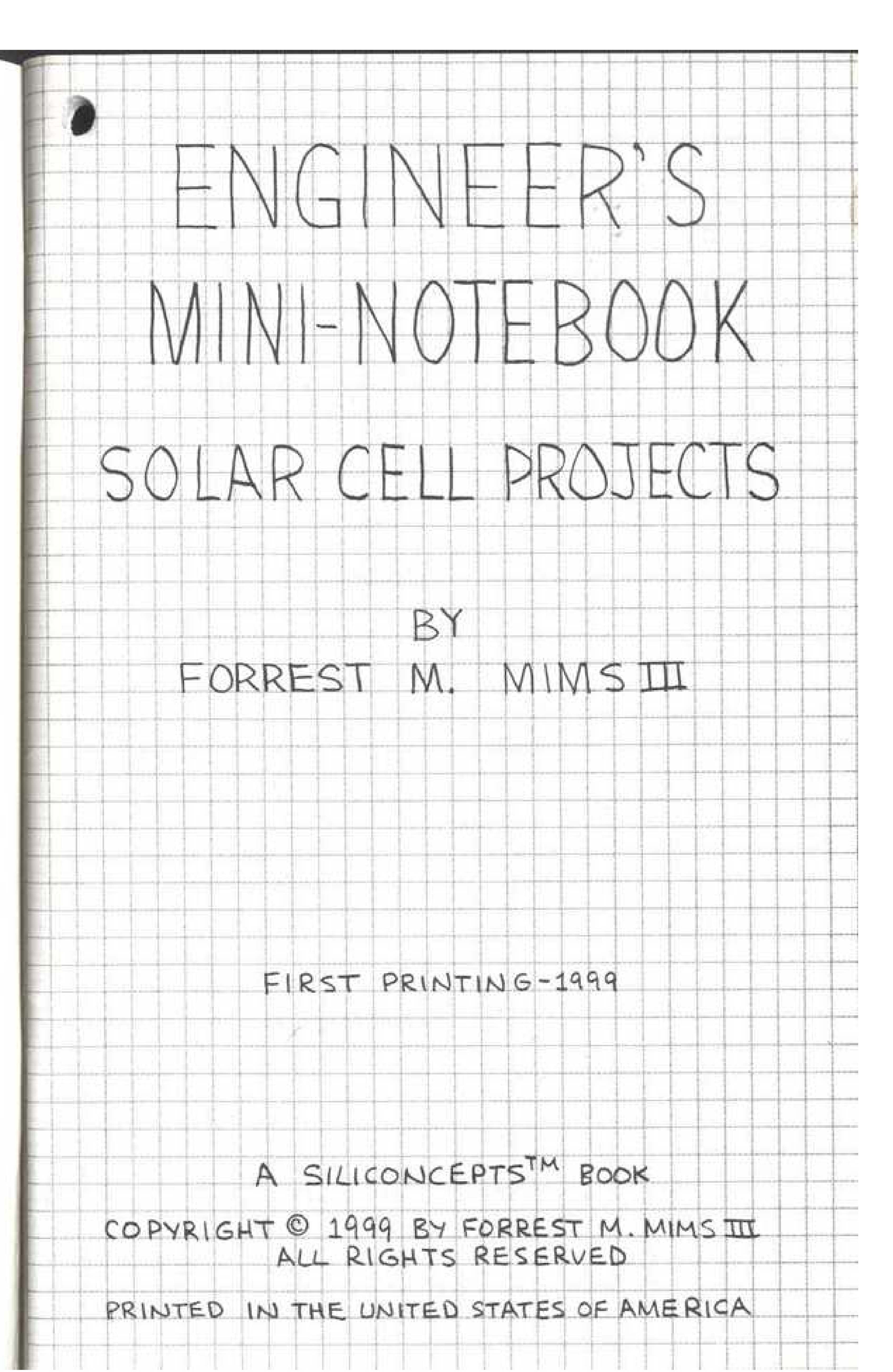
Build these solar projects:

- Battery charger
- Light meter
- Radiometer
- Solar-powered motor
- Light-triggered relay
- Break-beam systems and more



Forrest M. Mims III





ENGINEER'S MINI-NOTEBOOK

SOLAR CELL PROJECTS

BY
FORREST M. MIMS III

FIRST PRINTING - 1999

A SILICONCEPTS™ BOOK

PRINTED IN THE UNITED STATES OF AMERICA

ABOUT THE MINI-NOTEBOOK SERIES

WHERE TO FIND PARTS

ELECTRONIC PARTS IN THIS BOOK ARE AVAILABLE FROM RADIOSHACK STORES OR FROM RADIOSHACK UNLIMITED (RSU). SOME PARTS HAVE MORE THAN ONE DESIGNATION. FOR EXAMPLE, THE POPULAR 2N2222 TRANSISTOR CAN BE REPLACED BY THE 2N2222A, THE MPS2222 AND THE MPS2222A.

PLEASE READ THIS

THIS BOOK INCLUDES STANDARD CIRCUITS AND CIRCUITS DESIGNED BY FORREST M. MIMS III. EACH CIRCUIT WAS BUILT AND TESTED AT LEAST TWICE. VARIATIONS IN COMPONENTS AND CONSTRUCTION METHODS MAY GIVE RESULTS THAT DIFFER FROM THOSE DESCRIBED HERE. THEREFORE THE AUTHOR AND RADIOSHACK ARE NOT RESPONSIBLE FOR THE SUITABILITY OF THE CIRCUITS FOR ANY APPLICATION. SINCE WE HAVE NO CONTROL OVER THE USE OF INFORMATION IN THIS BOOK, WE ASSUME NO LIABILITY FOR SUCH USE. IT IS YOUR RESPONSIBILITY TO DETERMINE IF COMMERCIAL USE, SALE OR MANUFACTURE OF ANY DEVICE BASED ON INFORMATION IN THIS BOOK INFRINGES ANY PATENT, COPYRIGHT OR OTHER RIGHTS.

FOR MORE INFORMATION

DUE TO THE MANY INQUIRIES RECEIVED BY THE AUTHOR AND RADIOSHACK, IT IS IMPOSSIBLE TO PROVIDE CUSTOM CIRCUIT DESIGNS AND TECHNICAL ADVICE. YOU CAN LEARN MORE ABOUT ELECTRONICS BY READING ELECTRONICS MAGAZINES. ALSO SEE RADIOSHACK'S "GETTING STARTED IN ELECTRONICS" AND OTHER MINI-NOTEBOOKS IN THIS SERIES. YOU CAN ALSO FIND INFORMATION ON THE INTERNET NEWSGROUP SCI.ELECTRONICS.

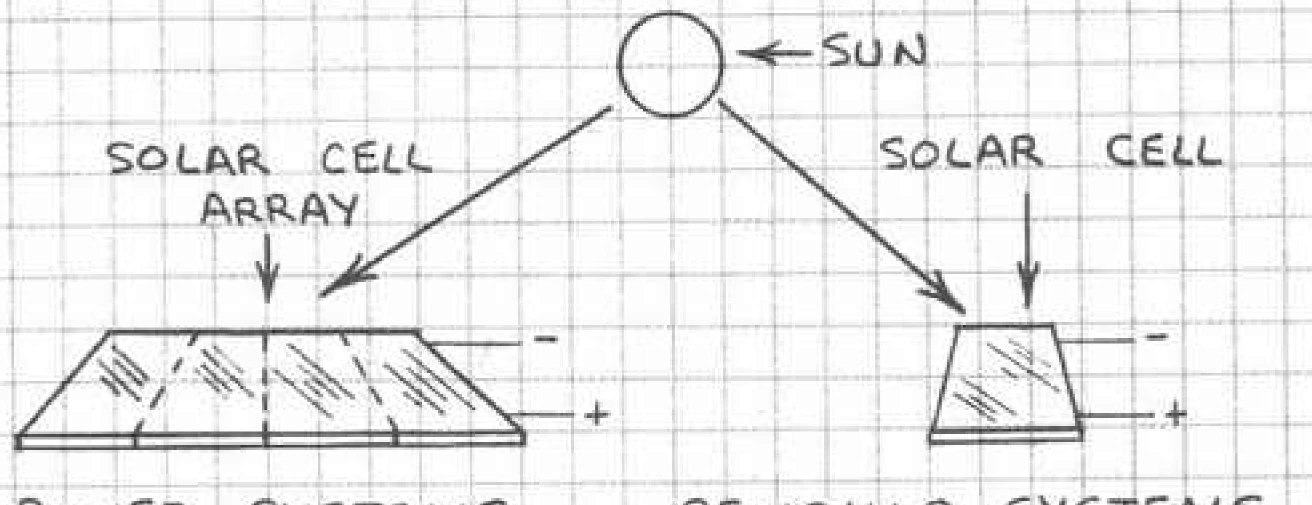
CONTENTS

INTRODUCTION

SOLID-STATE PHOTOVOLTAIC SOLAR CELLS TRANSFORM SUNLIGHT DIRECTLY INTO ELECTRICITY. THEY ARE AMONG THE MOST IMPORTANT SUNLIGHT-TO-ELECTRICITY CONVERTERS THAT HAVE BEEN INVENTED.

POWER GENERATION IS BY FAR THE MOST IMPORTANT APPLICATION FOR SOLAR CELLS AND ARRAYS. THEREFORE THIS MINI-NOTEBOOK INCLUDES BASIC INFORMATION ABOUT THE SUN AND SOLAR ENERGY. HOW SOLAR CELLS AND SOLAR CELL ARRAYS ARE USED TO CHARGE STORAGE BATTERIES AND TO DIRECTLY POWER SOME CIRCUITS IS ALSO COVERED.

IT'S IMPORTANT TO KNOW THAT SOLAR CELLS HAVE MANY APPLICATIONS UNRELATED TO SOLAR POWER. THIS IS BECAUSE SOLAR CELLS WORK VERY WELL AS RELATIVELY INEXPENSIVE AND SENSITIVE LIGHT SENSORS. THIS MINI-NOTEBOOK DESCRIBES MANY USES FOR SOLAR CELLS AS LIGHT SENSORS. VARIOUS CIRCUITS THAT USE SOLAR CELLS AS LIGHT SENSORS ARE ALSO GIVEN.



POWER SYSTEMS	SENSING SYSTEMS
1. CHARGE STORAGE BATTERIES.	1. DETECT SUNLIGHT.
2. POWER CIRCUITS DIRECTLY.	2. DETECT LIGHT FROM LEDS, LAMPS AND OTHER SOURCES.

SOLAR ENERGY MILESTONES

FOR THOUSANDS OF YEARS PEOPLE HAVE USED SUNLIGHT TO WARM THEIR HOMES. SOCRATES (470-399 B.C.) TAUGHT THE IMPORTANCE OF PLACING HOMES SO THE SUN'S WARMING RAYS COULD WARM THE INTERIOR ROOMS DURING WINTER.

HERE ARE JUST A FEW HIGHLIGHTS OF HISTORIC SOLAR ENERGY DEVELOPMENTS:

DESTRUCTION OF ROMAN FLEET (212 B.C.) – ARCHIMEDES IS REPORTED TO HAVE IGNITED INVADING ROMAN SHIPS BY MEANS OF REFLECTED SUNLIGHT.

DIAMOND MELTED (1695) – TWO ITALIAN EXPERIMENTERS SUCCEEDED IN MELTING A DIAMOND USING FOCUSED SUNLIGHT.

SOLAR FURNACE (1774) – THE FRENCH CHEMIST ANTOINE-LAURENT LAVOISIER MADE A SOLAR FURNACE THAT MELTED PLATINUM.

SOLAR-POWERED PRINTING PRESS (1878) – A LARGE PARABOLIC REFLECTOR COLLECTED ENOUGH SUNLIGHT TO POWER A PRINTING PRESS.

SOLAR STEAM ENGINE (1901) – A. G. ENEAS DESIGNED A SOLAR STEAM ENGINE THAT PUMPED IRRIGATION WATER IN ARIZONA. SUNLIGHT WAS COLLECTED BY 1,788 MIRRORS INSTALLED IN A FIXTURE THAT RESEMBLED A GIANT UMBRELLA 33.5 FEET (ABOUT 10 METERS) IN DIAMETER.

SOLAR ENGINE (1908) – JOHN BOYLES AND H.E. WILLSIE DEMONSTRATED A 15-HORSE-POWER ENGINE POWERED BY POOLS OF WATER THAT CAPTURED AND STORED THE HEAT FROM SUNLIGHT.

SOLAR ELECTRICAL PLANT (1913) – FRANK SHUMAN AND C.V. BOYS BUILT THE WORLD'S FIRST SOLAR-POWERED ELECTRICAL PLANT NEAR CAIRO, EGYPT. THE HUGE FACILITY USED SEVEN SOLAR COLLECTORS, EACH 204 FEET (ABOUT 62 METERS) LONG. THE COLLECTORS HAD A TOTAL AREA OF 13,000 SQUARE FEET (ABOUT 1,208 SQUARE METERS). THEY AUTOMATICALLY TRACKED THE SUN.

SOLAR OVEN (1925) – C. G. ABBOT OF THE SMITHSONIAN INSTITUTION COOKED MEALS USING A SOLAR-POWERED OVEN AT HIS SUN OBSERVATORY ON MOUNT WILSON, CALIFORNIA.

SOLAR FURNACE (1950'S) – FRENCH SCIENTIST FELIX TROMBE DESIGNED THE WORLD'S LARGEST SOLAR FURNACE. THIS FACILITY, WHOSE 9,000 MIRRORS ARE INSTALLED ON THE SIDE OF A BUILDING, CAN REACH THE TEMPERATURE OF THE SUN'S SURFACE, 10,000° FAHRENHEIT (ABOUT 5,538° CELSIUS).

SILICON SOLAR CELL (1954) – GERALD PEARSON, DARYL CHAPIN AND CALVIN FULLER OF BELL LABORATORIES DEVELOPED THE FIRST SUCCESSFUL SILICON SOLAR CELL. THIS DEVELOPMENT LED TO THE MODERN ERA OF PHOTOVOLTAIC SOLAR POWER CONVERSION.

MID-EAST OIL CRISIS (1970'S) – THE OIL CRISIS OF THE 1970'S STIMULATED SIGNIFICANT NEW RESEARCH IN SOLAR ENERGY. OLD KINDS OF SOLAR ENERGY SYSTEMS WERE IMPROVED AND NEW KINDS WERE DEVELOPED.

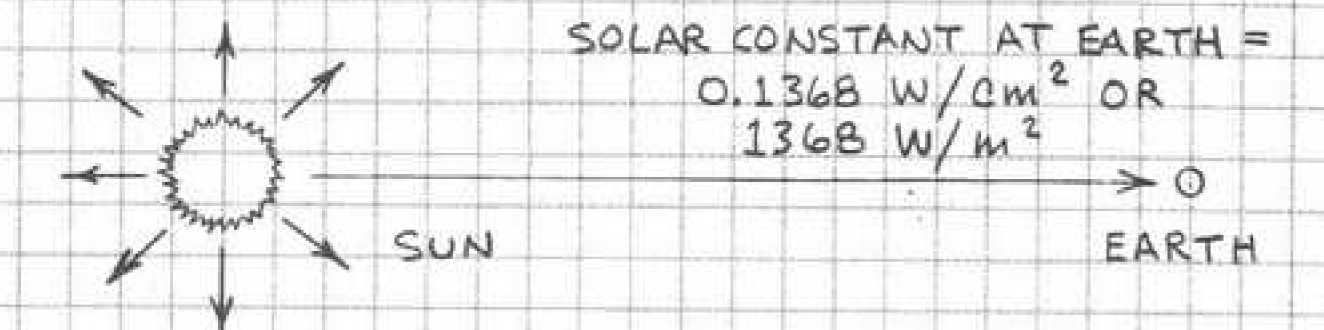
THIN-FILM SOLAR CELL (1980'S) – MANY KINDS OF SOLAR CELLS HAVE BEEN DEVELOPED, BUT THIN-FILM CELLS OF SILICON AND OTHER SEMICONDUCTORS ARE AMONG THE MOST IMPORTANT. THEY CAN BE MADE AS FLEXIBLE SHEETS MUCH LARGER THAN STANDARD SILICON SOLAR CELLS.

ENERGY FROM THE SUN

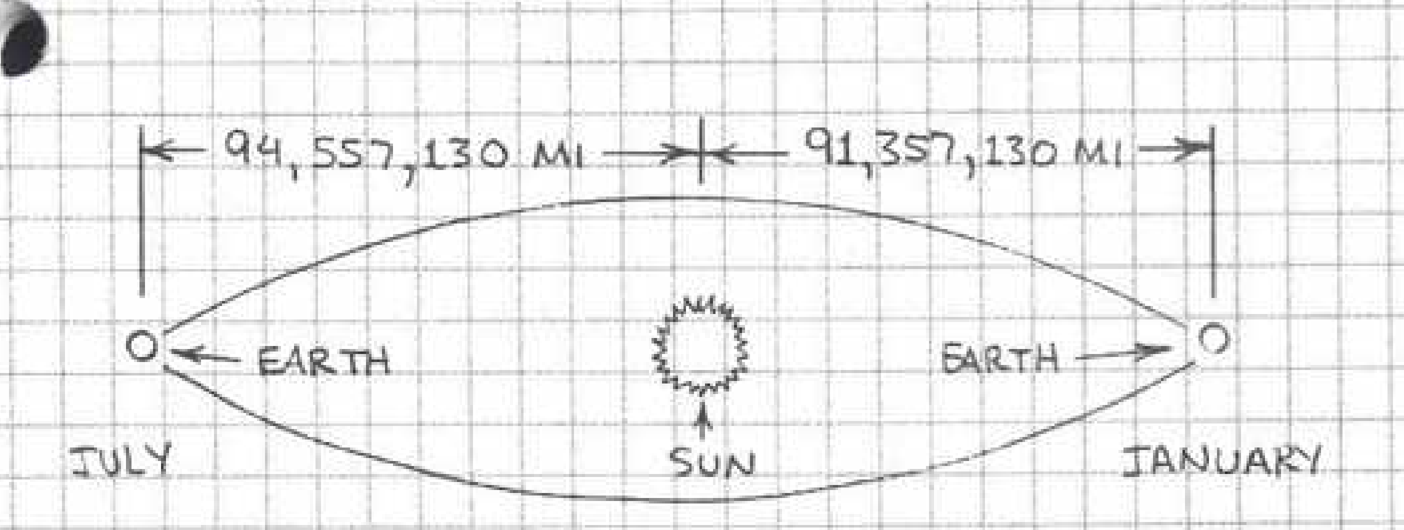
THE SUN EMITS AN INCREDIBLE AMOUNT OF ELECTROMAGNETIC RADIATION. THE TOTAL RADIATED POWER IS 3.83×10^{23} KILOWATTS (KW) OR 383,000,000,000,000,000,000,000,000 WATTS. MOST OF THIS RADIATION IS LOST TO SPACE. ONLY A TINY FRACTION IS INTERCEPTED BY EARTH AND THE OTHER PLANETS. ACCORDING TO THE SOLAR ENERGY INDUSTRIES ASSOCIATION (SEIA), ALL THE ELECTRICITY CONSUMED IN THE UNITED STATES COULD BE PROVIDED BY PHOTOVOLTAIC SOLAR CELL MODULES COVERING 0.3 % OF THE LAND AREA OF THE U.S.

THE SOLAR CONSTANT

THE MEAN AMOUNT OF SUNLIGHT AT THE TOP OF EARTH'S ATMOSPHERE IS CALLED THE SOLAR CONSTANT. MEASUREMENTS MADE BY SEVERAL SATELLITES SHOW THAT THE SOLAR CONSTANT IS 136.8 WATTS PER SQUARE CENTIMETER.



THE SUNLIGHT INTENSITY AT EARTH VARIES BECAUSE EARTH'S ORBIT AROUND THE SUN IS SLIGHTLY ELLIPTICAL. THE MEAN DISTANCE OF EARTH FROM THE SUN IS 92,957,130 MILES (149,600,000 KILOMETERS). IN EARLY JANUARY EARTH IS ABOUT 1,600,000 MILES (2,575,000 KM) CLOSER TO THE SUN. IN EARLY JULY EARTH IS ABOUT 1,600,000 MILES (2,575,000 KM) FARTHER FROM THE SUN. (SEE DRAWING ON FACING PAGE.)



THE DIFFERENCE IN THE INTENSITY OF SUNLIGHT BETWEEN PERIHELION (CLOSEST POINT) AND APHELION (FARTHEST POINT) IS ABOUT 6.7%. USE THE SOLAR CONSTANT TABLE TO FIND THE SOLAR CONSTANT FOR THE FIRST DAY OF ANY MONTH.

SOLAR CONSTANT TABLE

MULTIPLY THE MEAN SOLAR CONSTANT (1,368 WATTS PER SQUARE METER OR 136.8 MILLIWATS PER SQUARE CENTIMETER) BY THE CORRECTION NUMBERS IN THIS TABLE TO FIND THE ACTUAL SOLAR IRRADIANCE ON THE GIVEN DATES.

JANUARY	1.0335	JULY	0.9666
FEBRUARY	1.0288	AUGUST	0.9709
MARCH	1.0173	SEPTEMBER	0.9828
APRIL	1.0009	OCTOBER	0.9995
MAY	0.9841	NOVEMBER	1.0164
JUNE	0.9741	DECEMBER	1.0288

FROM KINSELL L. COULSON, "SOLAR AND TERRESTRIAL RADIATION," ACADEMIC PRESS, 1975.

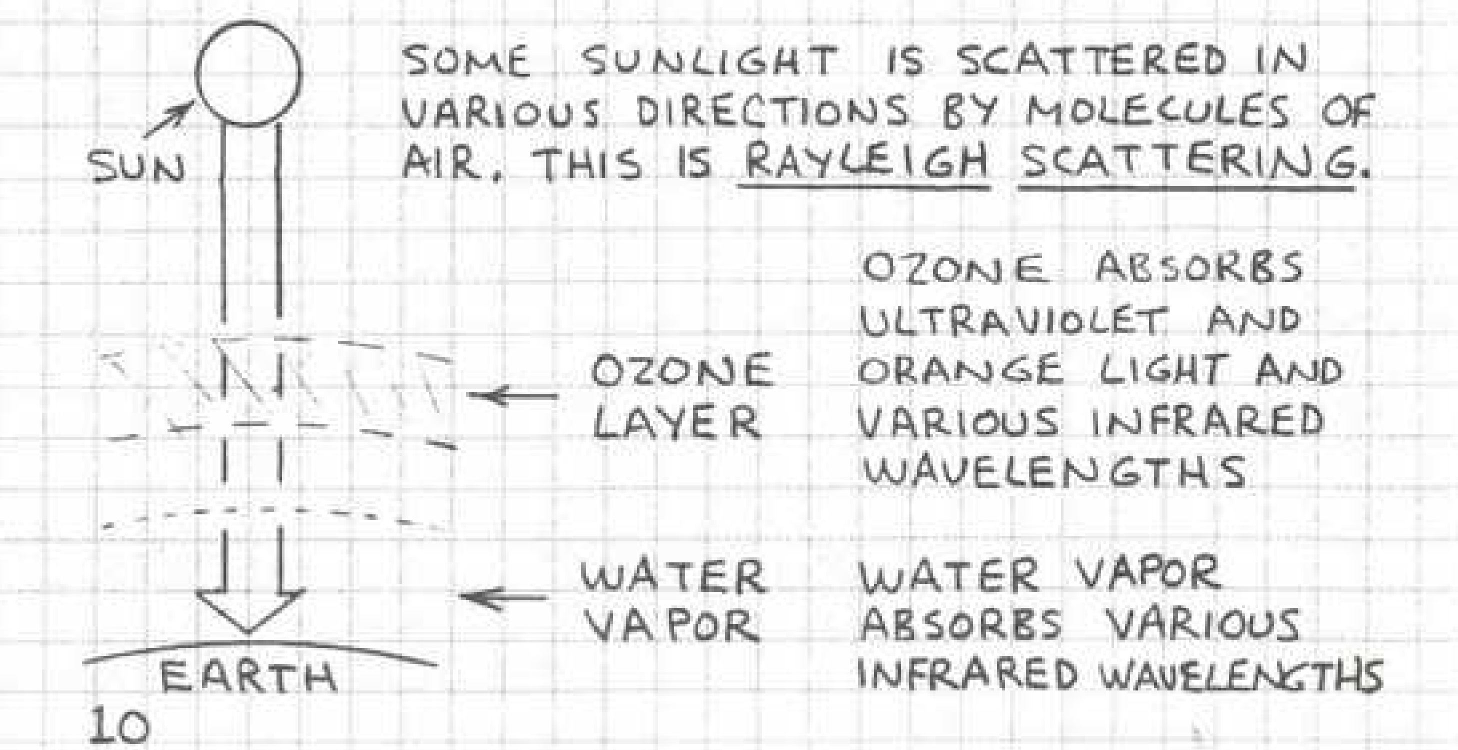
EXAMPLE: WHAT IS THE SUN'S IRRADIANCE AT THE TOP OF THE ATMOSPHERE ON MAY 1? THE IRRADIANCE ON MAY 1 IS 0.9841 OF THE MEAN SOLAR CONSTANT OF 136.8 MILLIWATTS PER SQUARE CENTIMETER. 0.9841×136.8 IS 134.625 MILLIWATTS PER SQUARE CENTIMETER.

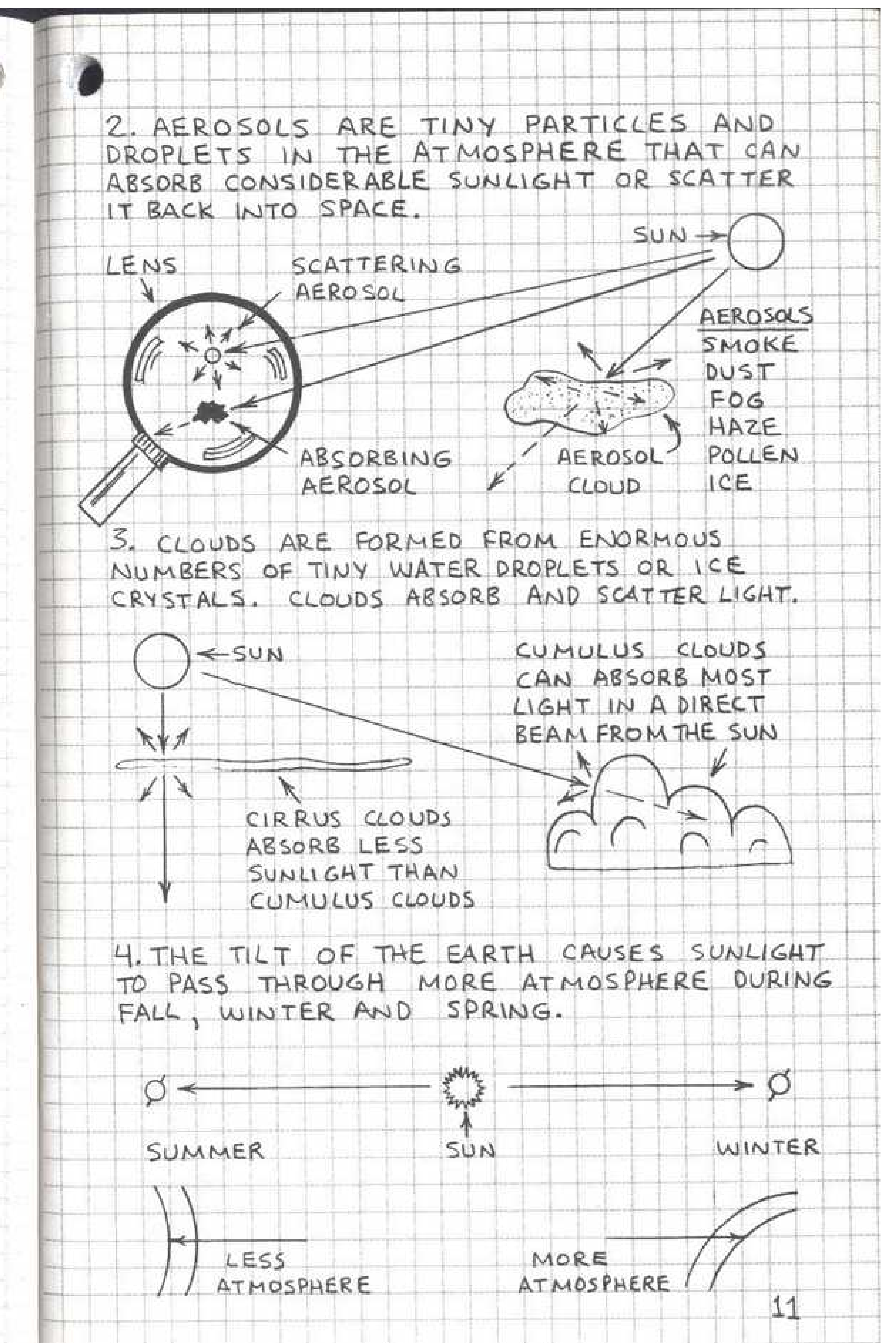
SUNLIGHT AND THE ATMOSPHERE

A SOLAR CELL ON A SATELLITE RECEIVES AT LEAST 15% MORE SOLAR ENERGY THAN AN IDENTICAL SOLAR CELL ON EARTH. FOR EXAMPLE, AT NOON ON JULY 1 THE SOLAR IRRADIANCE AT ALBUQUERQUE, NEW MEXICO, IS ABOUT 100 MILLIWATTS PER SQUARE CM (100 mW/cm^2) IF THE SUN IS NOT BLOCKED BY A CLOUD. FROM THE SOLAR CONSTANT TABLE (P. 9) THE IRRADIANCE AT THE TOP OF THE ATMOSPHERE ON JULY 1 IS 0.9666 × 136.8 mW/cm^2 OR 132.2 mW/cm^2. THUS ONLY 75.6% OF THE INTENSITY OF THE SUNLIGHT AT THE TOP OF THE ATMOSPHERE REACHES ALBUQUERQUE ON JULY 1. ALBUQUERQUE IS ABOUT 1 MILE (1.6 KILOMETERS) ABOVE SEA LEVEL AND THE AIR IS OFTEN DRY. LESS SUNLIGHT REACHES REGIONS NEARER SEA LEVEL, ESPECIALLY WHEN THE AIR IS MOIST. MUCH LESS SUNLIGHT IS RECEIVED EVERYWHERE DURING WINTER AND WHEN CLOUDS BLOCK THE SKY.

HERE ARE SOME OF THE CHIEF FACTORS THAT AFFECT SUNLIGHT:

1. WATER VAPOR, OZONE AND OTHER GASES IN THE ATMOSPHERE ABSORB SUNLIGHT.



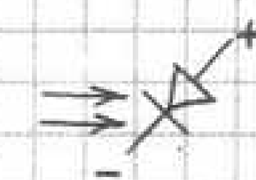


2. AEROSOLS ARE TINY PARTICLES AND DROPLETS IN THE ATMOSPHERE THAT CAN ABSORB CONSIDERABLE SUNLIGHT OR SCATTER IT BACK INTO SPACE.

3. CLOUDS ARE FORMED FROM ENORMOUS NUMBERS OF TINY WATER DROPLETS OR ICE CRYSTALS. CLOUDS ABSORB AND SCATTER LIGHT.

4. THE TILT OF THE EARTH CAUSES SUNLIGHT TO PASS THROUGH MORE ATMOSPHERE DURING FALL, WINTER AND SPRING.

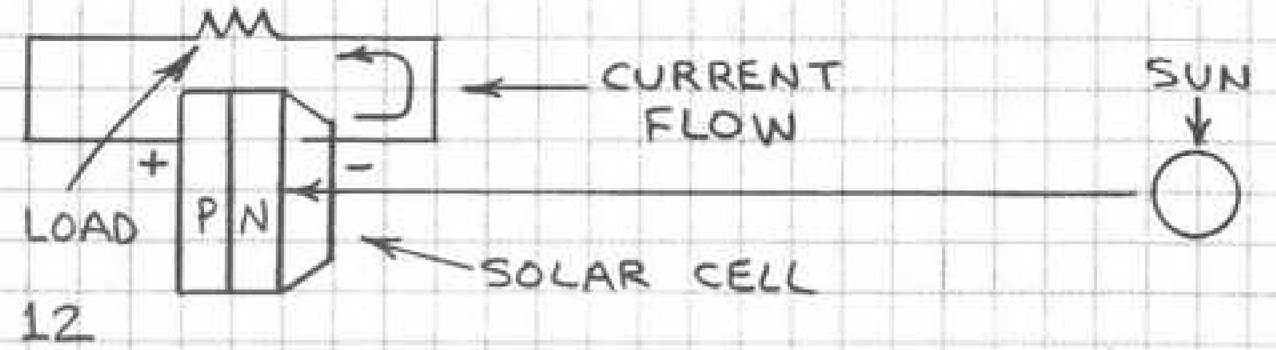
SOLAR CELLS



MANY SEMICONDUCTORS WILL GENERATE ELECTRICITY FROM SUNLIGHT. THE MOST COMMON AND BEST DEVELOPED SOLAR CELLS ARE MADE FROM SILICON. SINCE SILICON FORMS 27.7% OF EARTH'S CRUST, SILICON SOLAR CELLS ARE POTENTIALLY INEXPENSIVE. BUT TRANSFORMING SILICON INTO SOLAR CELLS IS AN EXPENSIVE PROCESS THAT REQUIRES CONSIDERABLE ELECTRICITY.

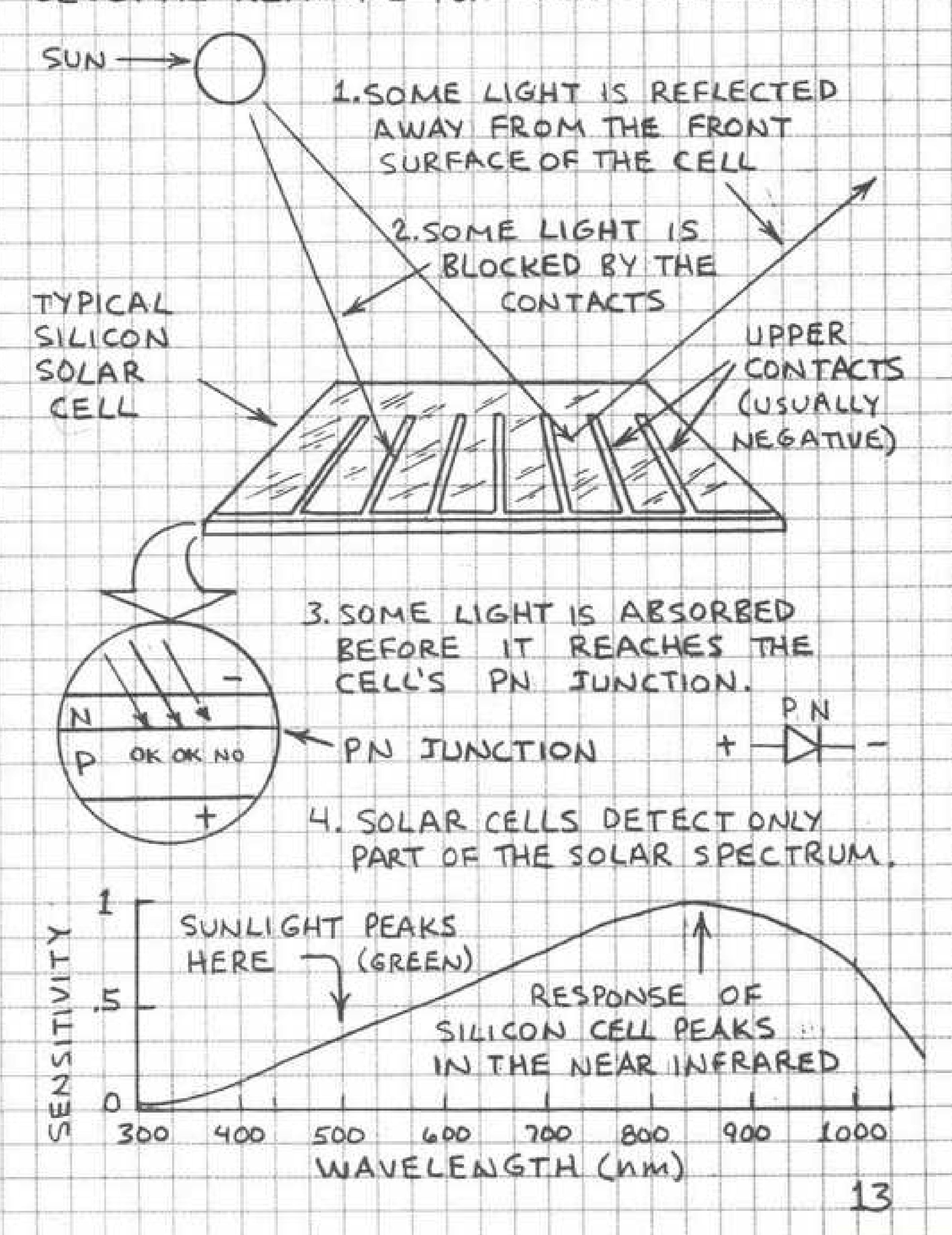
HOW SOLAR CELLS WORK

LIGHT CONSISTS OF PACKETS OF ENERGY CALLED PHOTONS THAT TRAVEL IN A WAVE-LIKE FASHION. WHEN PHOTONS STRIKE SILICON ATOMS THEY DISLODGE ELECTRONS. THE MISSING ELECTRONS LEAVE BEHIND POSITIVELY CHARGED ATOMS. THESE ATOMS ATTRACT FREE ELECTRONS IN THE SILICON. THIS RANDOM MOVEMENT OF ELECTRONS CAN BE CONVERTED INTO A FLOW OF ELECTRONS IF A PN JUNCTION IS FORMED IN THE SILICON. ELECTRONS DISLODGED BY PHOTONS NEAR THE PN JUNCTION ARE ATTRACTED TO THE P SIDE OF THE JUNCTION. THE RESULT IS A FLOW OF ELECTRICAL CURRENT WHEN LIGHT IS PRESENT. THE LEVEL OF CURRENT IN AMPERES IS DIRECTLY PROPORTIONAL TO THE LIGHT INTENSITY. THE POTENTIAL OF THE CURRENT IN VOLTS IS UNRELATED TO THE LIGHT INTENSITY. A TYPICAL SILICON SOLAR CELL GENERATES 0.45 TO 0.55 VOLT IN DIRECT SUNLIGHT.



SOLAR CELL EFFICIENCY

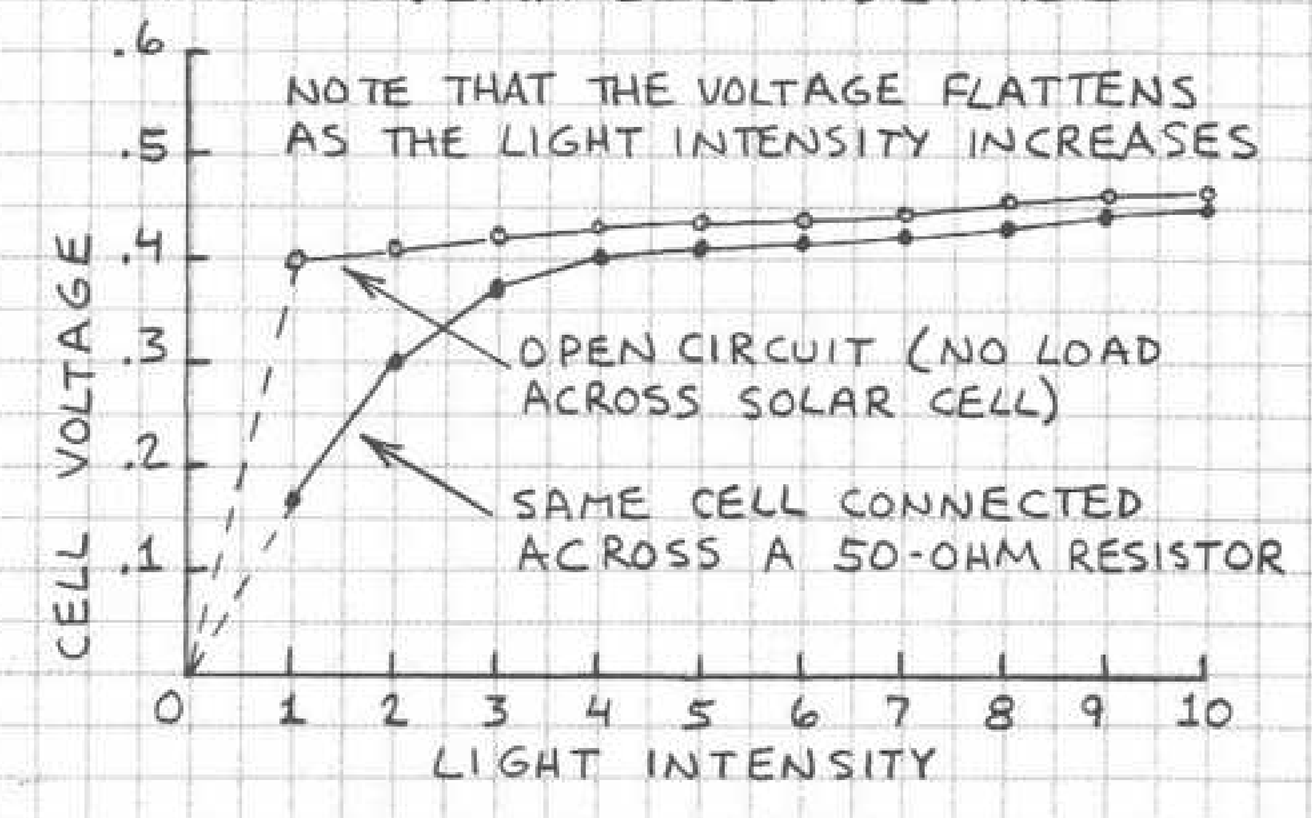
IF EVERY PHOTON STRIKING A SOLAR CELL DISLODGES AN ELECTRON, THE CELL WILL TRANSFORM NEARLY 100% OF THE LIGHT THAT STRIKES IT INTO ELECTRICITY. THE ACTUAL EFFICIENCY OF REAL SOLAR CELLS IS FROM ABOUT 5% TO 20%. THERE ARE SEVERAL REASONS FOR REDUCED EFFICIENCY:



SILICON SOLAR CELL RATINGS

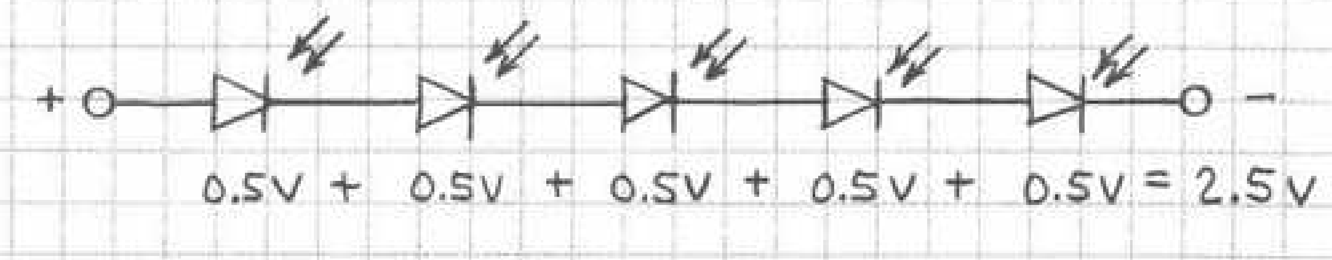
IT IS IMPORTANT TO READ AND UNDERSTAND SOLAR CELL RATINGS, ESPECIALLY WHEN THE CELLS ARE TO BE USED TO CHARGE A STORAGE CELL OR BATTERY.

SILICON SOLAR CELL VOLTAGE



INCREASING SOLAR CELL VOLTAGE

WHEN SOLAR CELLS ARE USED TO CHARGE STORAGE CELLS OR BATTERIES, SEVERAL CELLS MUST BE CONNECTED IN SERIES TO OBTAIN A SUFFICIENTLY HIGH VOLTAGE.

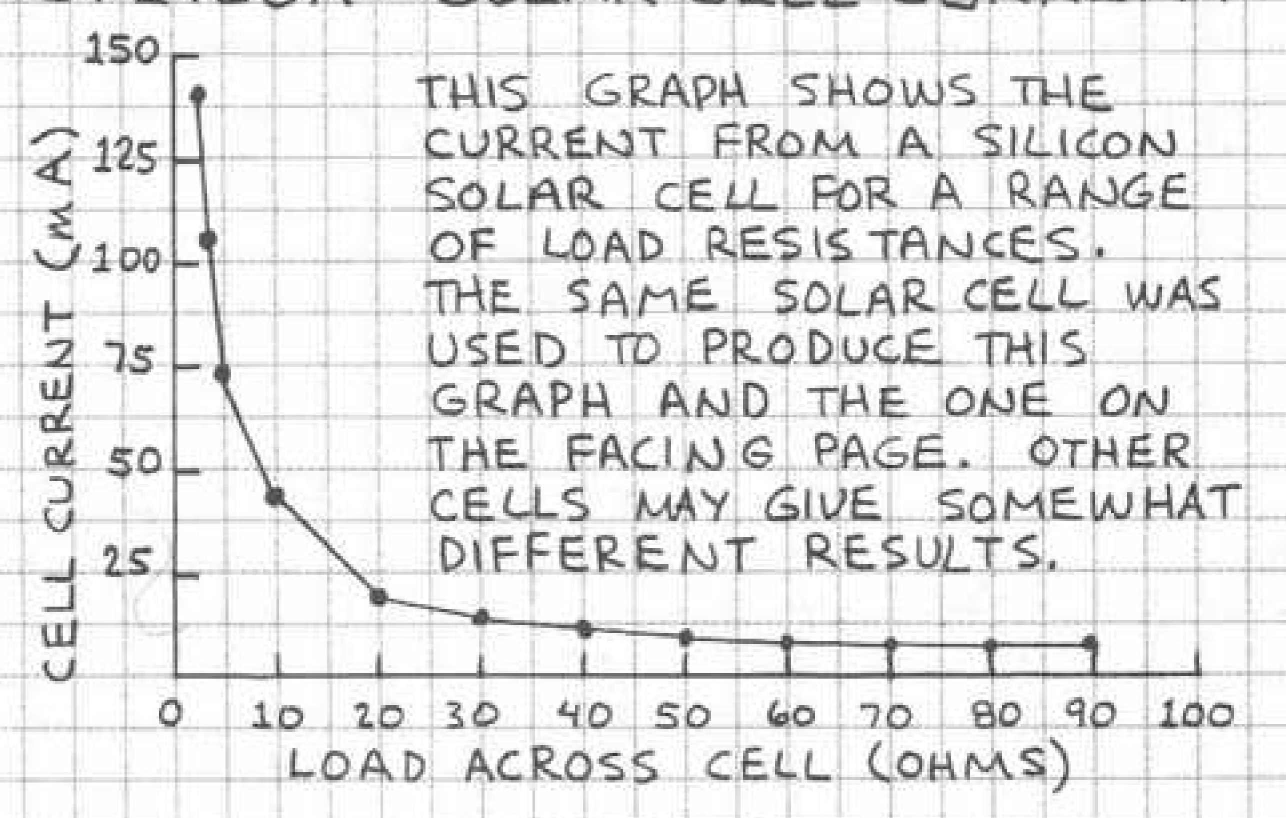


TYPICAL SERIES ARRAY:



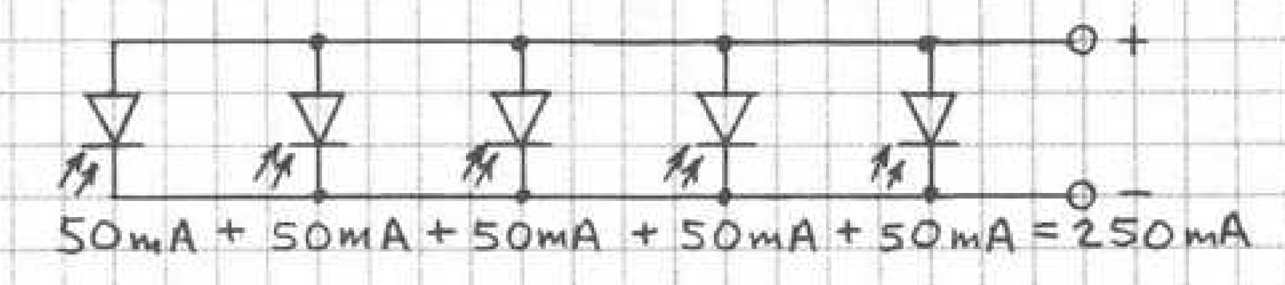
A STRING OF SOLAR CELLS CONNECTED IN SERIES OR IN PARALLEL (SEE BELOW) IS CALLED AN ARRAY. ALL THE CELLS IN AN ARRAY SHOULD BE EQUALLY ILLUMINATED. SHADING ONE CELL IN A 6.5-VOLT ARRAY DROPPED THE OUTPUT TO 6.2 VOLTS.

SILICON SOLAR CELL CURRENT



INCREASING SOLAR CELL CURRENT

CONNECTING SOLAR CELLS IN PARALLEL INCREASES THE OUTPUT CURRENT. THIS IS ESPECIALLY USEFUL WHEN CHARGING LARGE STORAGE BATTERIES.



TYPICAL PARALLEL ARRAY:



SOLDERING LEADS TO SOLAR CELLS

SOLAR CELLS OR SOLD WITH OR WITHOUT LEADS. SOLDERING LEADS TO SOLAR CELLS IS TRICKY, BUT YOU CAN SAVE MONEY IF YOU ARE WILLING TO SOLDER THE LEADS YOURSELF USING THE REFLOW SOLDERING METHOD DESCRIBED HERE. SOLAR CELLS ARE FRAGILE, SO USE CARE.

SUITABLE SOLDERING IRONS AND SOLDER ARE AVAILABLE FROM RADIOSHACK. SELECT A LOW-WATTAGE IRON OF ABOUT 15 TO 30 WATTS. USE 0.032-INCH OR SMALLER ROSIN CORE SOLDER. DO NOT USE ACID-CORE SOLDER.

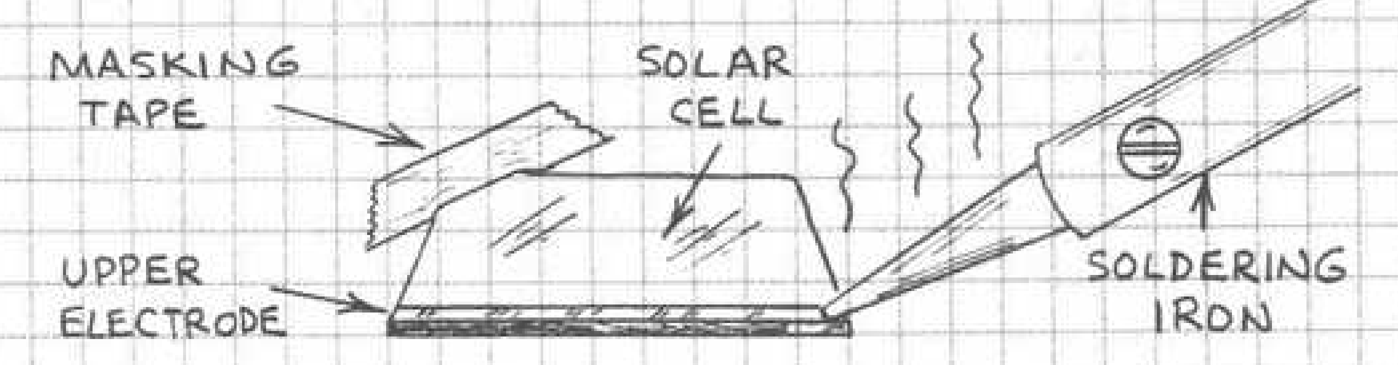
BE SURE TO TIN THE TIP OF THE SOLDERING IRON. FIRST, ALLOW THE IRON TO BECOME HOT ENOUGH TO MELT SOLDER. THEN MELT SOLDER OVER THE TIP OF THE SOLDERING IRON. CAREFULLY BRUSH OFF THE EXCESS SOLDER WITH A SOFT CLOTH. AVOID SPLASHING SOLDER ON YOURSELF OR OTHERS. A PROPERLY TINNED TIP WILL APPEAR SMOOTH AND SHINY.

FOLLOW THESE STEPS TO SOLDER LEADS TO A SOLAR CELL:

1. FIND A SAFE PLACE TO WORK. IT IS ESPECIALLY IMPORTANT THAT THE SOLDERING IRON'S POWER CORD BE SAFELY PLACED. SO BE SURE AN ELECTRICAL OUTLET IS NEARBY. CAUTION: A HOT SOLDERING IRON CAN BURN SKIN OR CLOTHING!

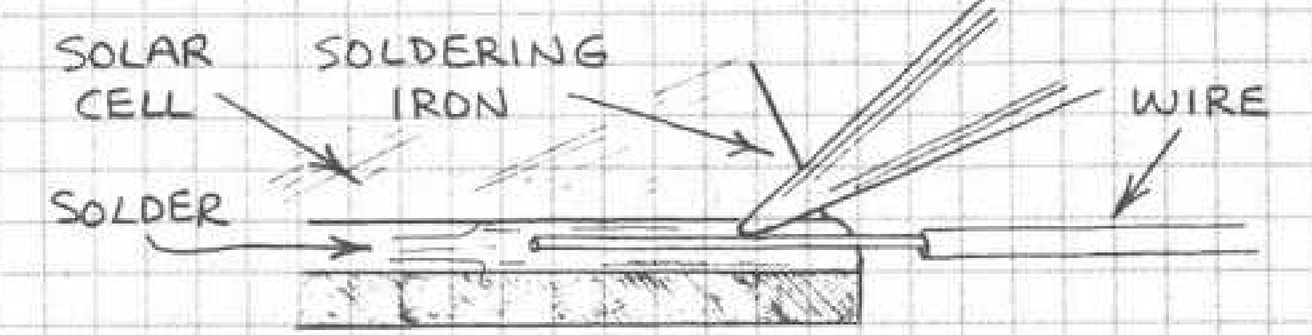
2. SILICON SOLAR CELLS HAVE ELECTRODES ON BOTH SIDES. THE ELECTRODE ON THE LIGHT-SENSITIVE, UPPER SURFACE IS A THIN STRIP OF METAL ALONG ONE EDGE OF THE CELL. PLACE THE CELL WITH THE TOP SIDE UP ON YOUR WORK SURFACE (A PIECE OF SCRAP WOOD IS BEST) AND USE A PIECE OF MASKING TAPE TO HOLD IT IN PLACE WHILE YOU SOLDER.

3. WHEN THE SOLDERING IRON IS HOT, GENTLY TOUCH THE EDGE OF THE TIP TO ONE END OF THE UPPER ELECTRODE. LIKE THIS:



4. AFTER A SECOND OR SO, TOUCH THE END OF A LENGTH OF SOLDER TO WHERE THE SOLDERING IRON TOUCHES THE ELECTRODE. ALLOW SOME SOLDER TO MELT ONTO THE ELECTRODE AND REMOVE THE IRON.

5. REMOVE ABOUT 0.2 INCH (5 mm) OF THE INSULATION FROM THE END OF SOME WRAPPING WIRE. PLACE THE EXPOSED END OF THE WIRE ALONG THE TOP OF THE SOLDER THAT YOU MELTED ONTO THE ELECTRODE AND THEN GENTLY PRESS THE SOLDERING IRON AGAINST THE WIRE AND REMELT THE SOLDER. WHEN THE WIRE PUSHES INTO THE MOLTEN SOLDER, HOLD THE WIRE VERY STILL AND REMOVE THE SOLDERING IRON.



6. AFTER THE SOLAR CELL COOLS, GENTLY REMOVE THE TAPE, FLIP THE CELL OVER AND TAPE IT IN PLACE AGAIN. FOLLOW STEPS 3-5 ABOVE TO SOLDER A LENGTH OF WRAPPING WIRE TO THE BACK ELECTRODE. AFTER THE WIRE SINKS INTO THE MOLTEN SOLDER, BE SURE TO KEEP THE WIRE VERY STILL WHILE THE SOLDER COOLS.

MOUNTING SOLAR CELLS

SOLAR CELLS ARE AVAILABLE UNMOUNTED OR INSTALLED IN VARIOUS KINDS OF PROTECTIVE ENCLOSURES. IT'S BEST TO INSTALL UNMOUNTED CELLS IN AN ENCLOSURE OR TO MOUNT THEM ON A PROTECTIVE PANEL. TWO METHODS THAT I HAVE USED ARE DESCRIBED HERE.

ADVANTAGES OF MOUNTED CELLS

1. SOLAR CELLS ARE BRITTLE AND EASILY BROKEN. MOUNTING THEM GREATLY REDUCES THE RISK OF BREAKAGE.

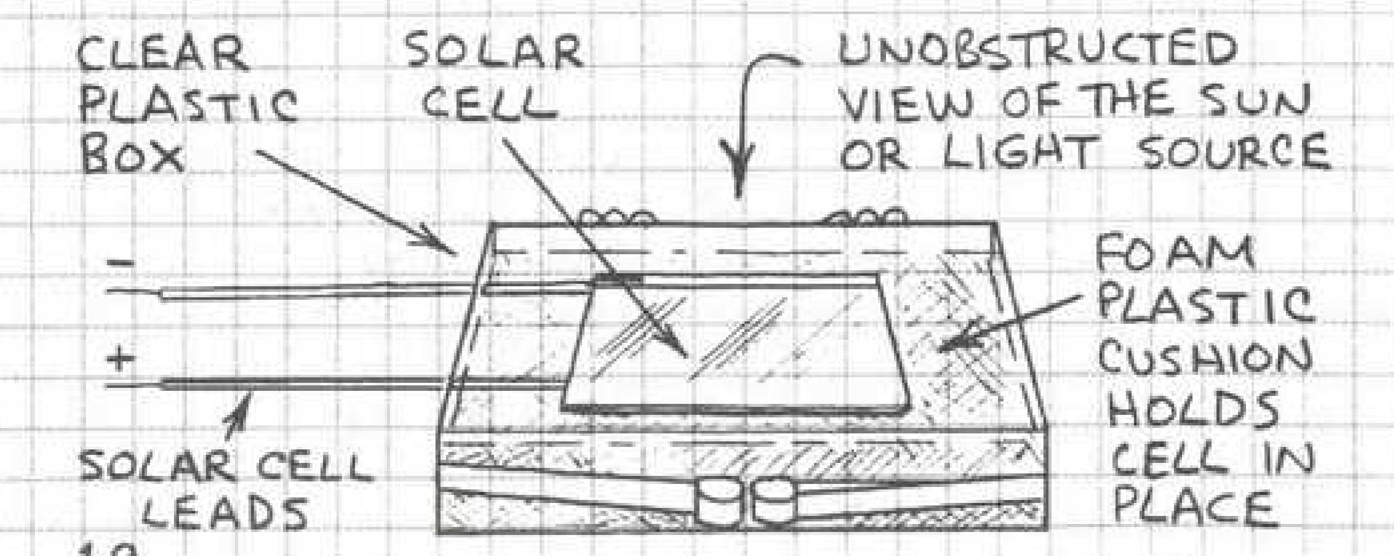
2. WIRE LEADS SOLDERED TO A SOLAR CELL ARE EASILY PULLED AWAY. MOUNTING THE CELL WILL PROTECT THE LEADS.

3. AN ENCLOSURE OR PANEL CAN BE MOUNTED ON THE CIRCUIT IT IS DESIGNED TO POWER.

4. AN ENCLOSURE OR PANEL PROTECTS THE SOLAR CELL(S) FROM MOISTURE AND DUST.

INSTALLING CELLS IN AN ENCLOSURE

ONE OR MORE SOLAR CELLS CAN BE EASILY INSTALLED IN A TRANSPARENT BOX.

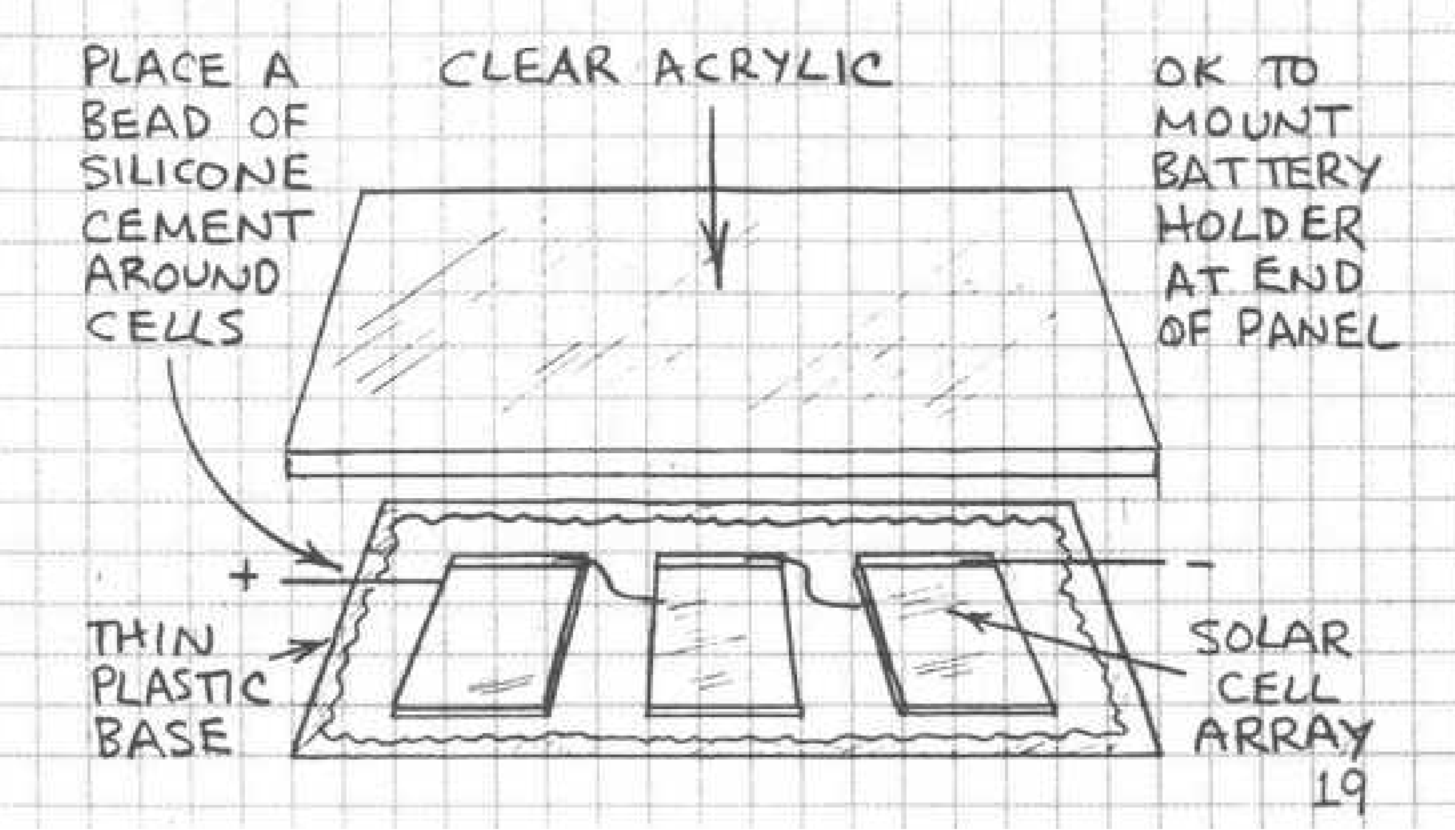


THE DRAWING ON THE FACING PAGE SHOWS A SOLAR CELL SANDWICHED BETWEEN A FOAM PLASTIC CUSHION AND THE LID OF A CLEAR PLASTIC BOX. YOU CAN ALSO SANDWICH THE CELL(S) BETWEEN THE LID AND A PLASTIC OR CARDBOARD LINER INSERTED IN THE LID AND CEMENTED IN PLACE.

I HAVE USED INDIVIDUAL RADIOSHACK SOLAR CELLS INSTALLED IN PLASTIC BOXES AS LIGHT SENSORS WITHOUT EVER DAMAGING A CELL OR BREAKING ITS LEADS. SERIES OR PARALLEL ARRAYS OF CELLS CAN BE INSTALLED IN LARGER PLASTIC BOXES. SOLDER THE CELLS TO ONE ANOTHER WITH SHORT LENGTHS OF WRAPPING WIRE. SECURE THE CELLS IN PLACE AS SHOWN ON THE FACING PAGE OR USE A LINER AS DESCRIBED ABOVE. BE SURE THE CONNECTION WIRES DO NOT BLOCK ANY OF THE CELLS.

MOUNTING SOLAR CELLS ON A PANEL

FOR MANY YEARS I HAVE USED HOMEMADE SOLAR CELL PANELS TO CHARGE FLASHLIGHT CELLS ON BICYCLE TRIPS. HERE'S HOW THEY ARE MADE:

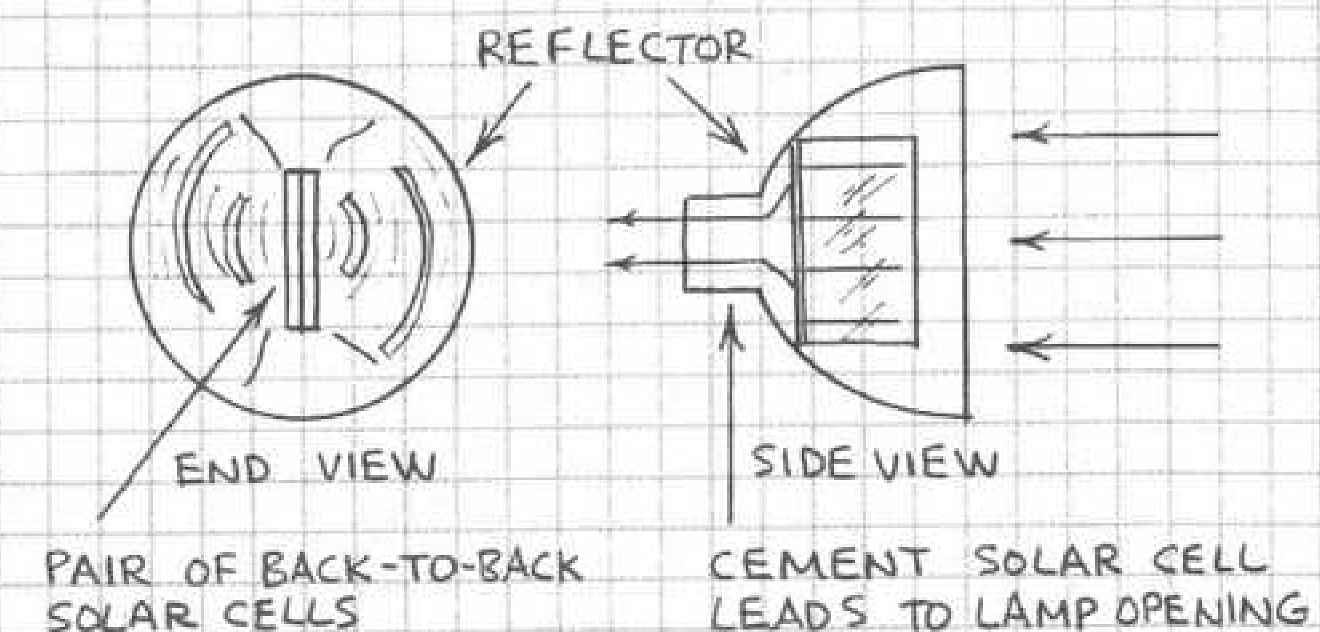


SOLAR CELL CONCENTRATORS

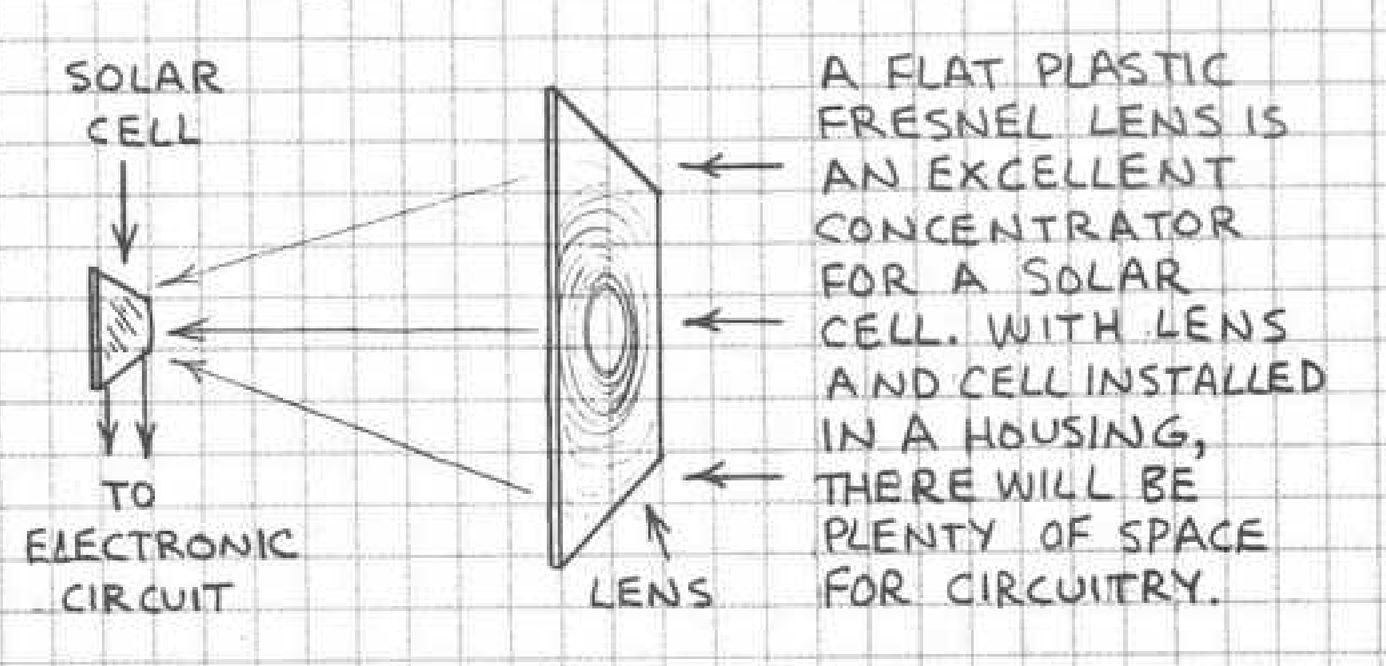
A SOLAR CELL CONCENTRATOR INCREASES THE AMOUNT OF LIGHT COLLECTED BY A SOLAR CELL. CONCENTRATORS ARE BEST USED IN APPLICATIONS IN WHICH SOLAR CELLS ARE USED AS LIGHT SENSORS FOR VARIOUS CIRCUITS RATHER THAN POWER GENERATORS. A CONCENTRATOR CAN BOOST THE POWER FROM A SOLAR CELL ILLUMINATED BY SUNLIGHT. BUT CONCENTRATORS ARE NOT ALWAYS PRACTICAL FOR THIS PURPOSE SINCE THEY CAN CAUSE A CELL TO BECOME OVERHEATED.

PARABOLIC REFLECTOR

LARGE FLASHLIGHTS THAT USE REPLACEABLE BULBS CAN BE USED AS CONCENTRATORS FOR SOLAR CELLS. MOUNT TWO CELLS BACK-TO-BACK WITH DOUBLE SIDED TAPE. CONNECT THE PLUS LEAD OF ONE CELL TO THE NEGATIVE LEAD OF THE SECOND CELL. EXTEND THE REMAINING LEADS THROUGH THE LAMP OPENING. USE AN ADHESIVE TO SECURE THE CELLS INSIDE THE REFLECTOR. THE FLASHLIGHT CASE HAS PLENTY OF ROOM TO INSTALL MANY KINDS OF LIGHT ACTUATED CIRCUITS.

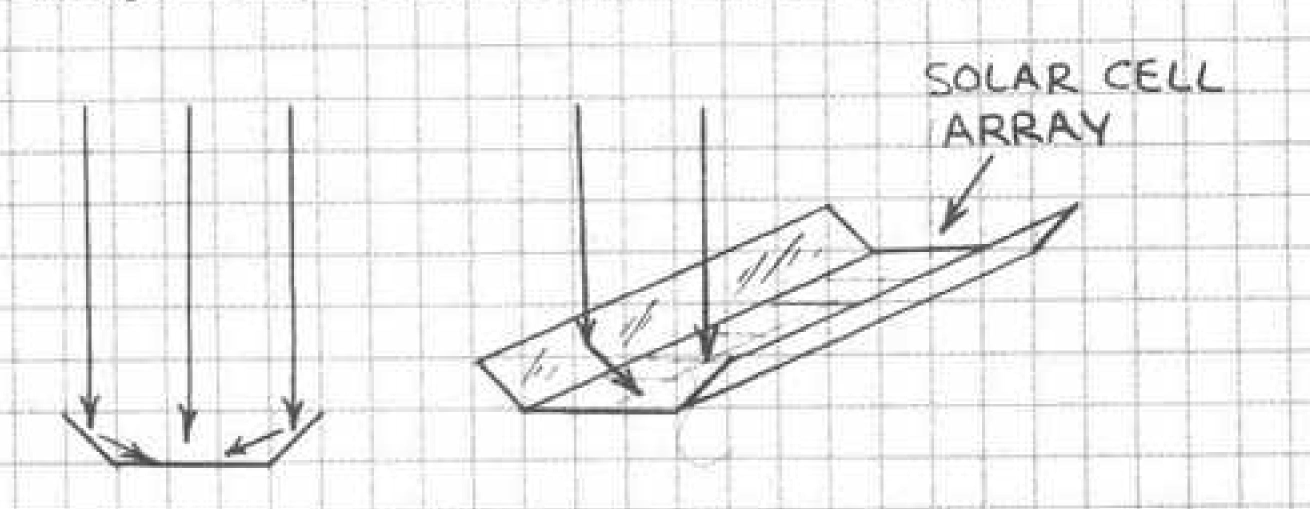


FRESNEL LENS



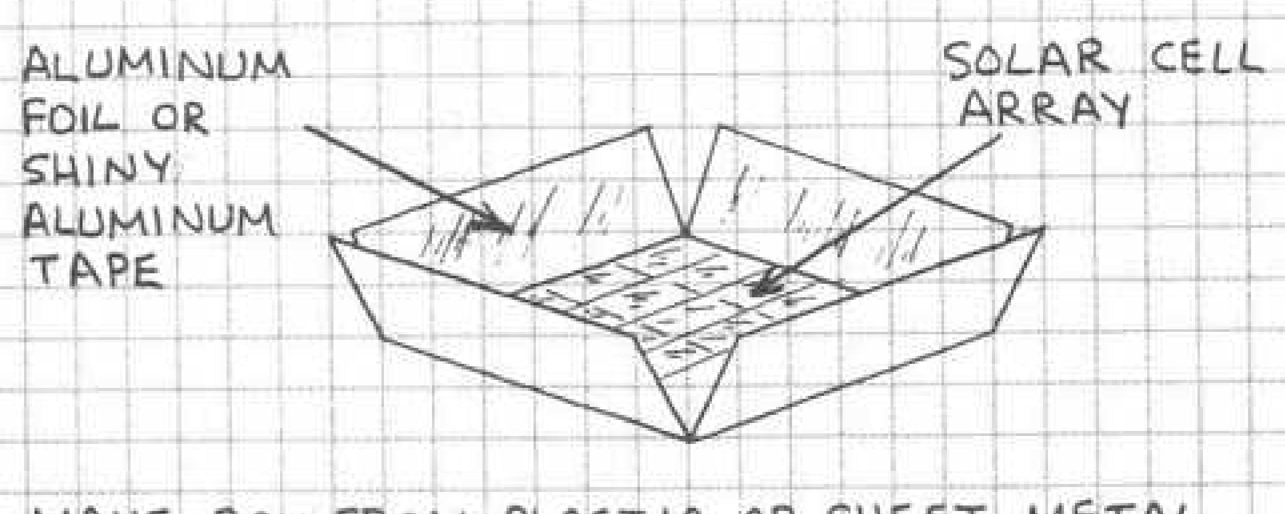
A FLAT PLASTIC FRESNEL LENS IS AN EXCELLENT CONCENTRATOR FOR A SOLAR CELL. WITH LENS AND CELL INSTALLED IN A HOUSING, THERE WILL BE PLENTY OF SPACE FOR CIRCUITRY.

TROUGH CONCENTRATOR



TROUGH CAN BE PLASTIC OR SHEET METAL LINED WITH SHINY ALUMINUM TAPE.

BOX CONCENTRATOR



MAKE BOX FROM PLASTIC OR SHEET METAL FOR BEST RESULTS.

SOLAR CELL BATTERY CHARGERS

LEAD-ACID AND NICKEL CADMIUM (NiCd) ARE THE MOST COMMON STORAGE BATTERIES. CERTAIN ALKALINE, LITHIUM AND OTHER TYPES CAN ALSO BE USED AS RECHARGEABLE STORAGE BATTERIES. WHEN CHARGING A STORAGE BATTERY YOU MUST OBSERVE SEVERAL PRECAUTIONS TO AVOID DAMAGE TO THE BATTERY OR ONE OF ITS CELLS. THESE PRECAUTIONS WILL ALSO GREATLY REDUCE THE POSSIBILITY OF FIRE OR EVEN EXPLOSION, WHICH CAN OCCUR WHEN A STORAGE BATTERY IS IMPROPERLY CHARGED.

STORAGE BATTERY PRECAUTIONS

1. CHARGE ONLY CELLS AND BATTERIES DESIGNED TO BE RECHARGED. CAUTION: NEVER ATTEMPT TO CHARGE OTHER KINDS OF BATTERIES! THEY MAY OVERHEAT, SWELL AND POSSIBLY EXPLODE.

2. NEVER EXCEED THE MAXIMUM ALLOWED CHARGING CURRENT FOR A STORAGE CELL OR BATTERY. INSTEAD OF REDUCING THE CHARGING TIME, THE CELL OR THE BATTERY MAY BE RUINED.

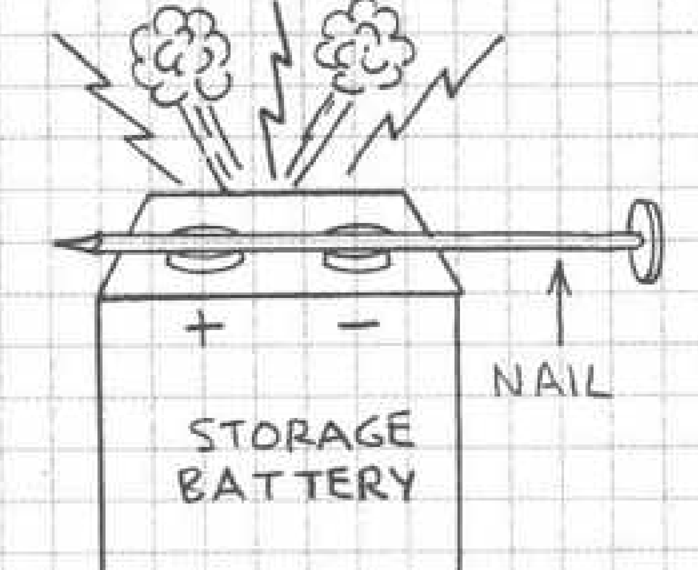
3. CHARGE MULTIPLE STORAGE CELLS IN SERIES INSTEAD OF IN PARALLEL.

CELLS IN SERIES: + —+|–+|–+|–— −

4. KEEP BATTERIES AWAY FROM DIRECT SUNLIGHT WHILE BEING CHARGED.

5. IF A BATTERY BECOMES HOT WHILE BEING CHARGED, IMMEDIATELY DISCONNECT IT OR REMOVE IT FROM THE SOLAR CHARGER. ALLOW IT TO COOL BEFORE USING IT.

6. NEVER SHORT THE TERMINALS OF A STORAGE CELL OR BATTERY! STORAGE CELLS HAVE A VERY LOW INTERNAL RESISTANCE. THIS MEANS THEY CAN PRODUCE A VERY HIGH CURRENT IF THEIR TERMINALS ARE SHORTED.



CAUTION!

DO NOT SHORT THE TERMINALS OF A STORAGE CELL OR BATTERY WITH A NAIL, COIN, METAL FOIL OR OTHER CONDUCTOR.

7. USE TAPE TO INSULATE THE EXPOSED TERMINALS OF STORAGE CELLS AND BATTERIES. OTHERWISE THE TERMINALS MIGHT BECOME ACCIDENTALLY SHORTED TOGETHER. WHEN POSSIBLE, USE AN INSULATED BATTERY HOLDER OR CONNECTION CLIPS WITH INSULATED LEADS.

8. IT'S BEST TO CHARGE NICKEL CADMIUM STORAGE CELLS AND BATTERIES WHEN THEY ARE FULLY DISCHARGED. THIS INCREASES THE TIME THESE CELLS WILL FUNCTION BETWEEN CHARGES.

9. NEVER GUESS ABOUT THE SPECIFICATIONS OF AN UNKNOWN OR UNMARKED BATTERY. THE SPECIFICATIONS OF BATTERIES SOLD BY RADIOSHACK ARE LISTED IN THE RADIOSHACK CATALOG. YOU CAN FIND THE SPECIFICATIONS OF BATTERIES VIA THE WORLD WIDE WEB. BEGIN YOUR SEARCH BY SELECTING ONE OF THE WEB SEARCH ENGINES. TYPE IN THE MANUFACTURER'S NAME AND THE WORD "BATTERY" OR "CELL" TO NARROW YOUR SEARCH.

SOLAR CELL BATTERY CHARGERS

SERIES ARRAYS OF SOLAR CELLS ARE USED TO CHARGE STORAGE CELLS AND BATTERIES. THE ARRAY MUST GENERATE A SLIGHTLY HIGHER VOLTAGE THAN THAT OF THE BATTERY BEING CHARGED. HERE ARE THE NUMBER OF SERIES-CONNECTED CELLS COMMONLY USED TO CHARGE SOME POPULAR BATTERY CONFIGURATIONS:

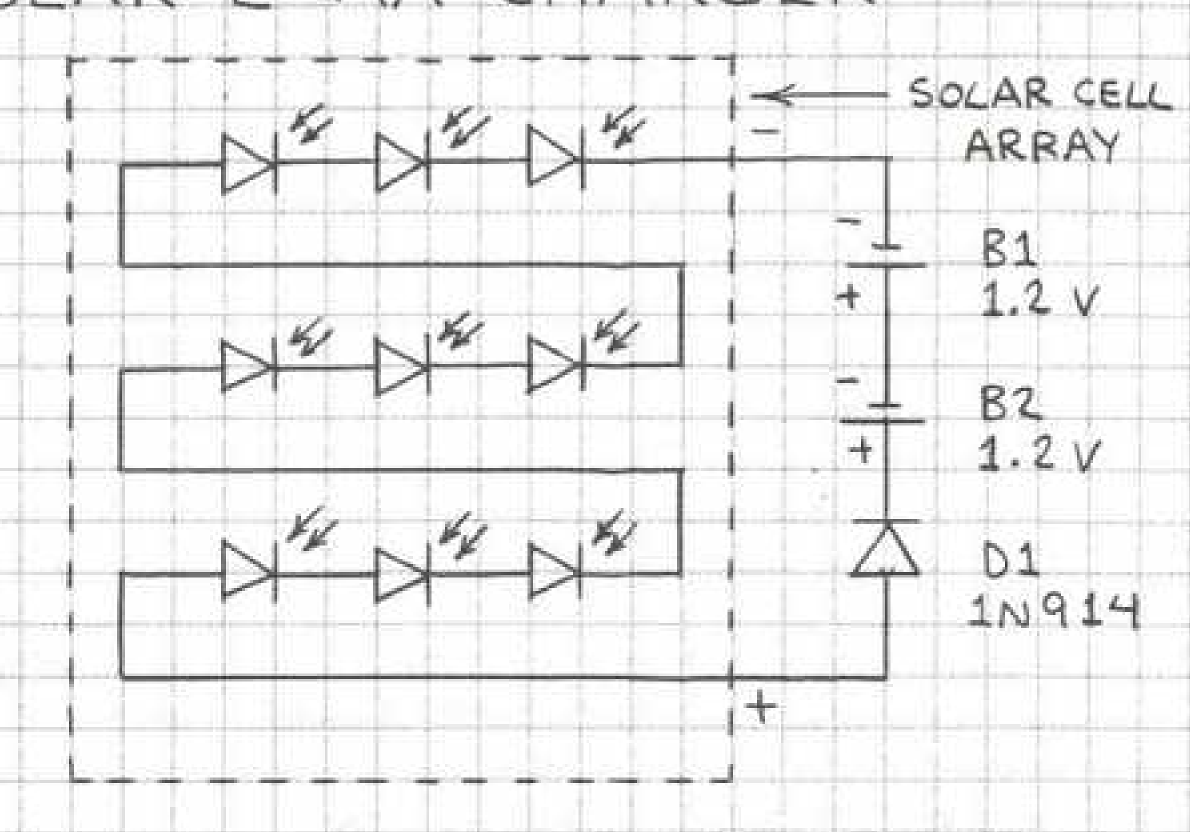
1 1.2-VOLT NiCd CELL — 4 SOLAR CELLS

2 1.2-VOLT NiCd CELLS IN SERIES — 9 SOLAR CELLS

4 1.2-VOLT NiCd CELLS IN SERIES — 18 SOLAR CELLS

1 12-VOLT LEAD-ACID BATTERY — 36 SOLAR CELLS

SOLAR 2×AA CHARGER



THIS CIRCUIT WILL CHARGE 2 AA NiCd CELLS. IF THE CELLS ARE FULLY DISCHARGED, SOLAR CELLS THAT GENERATE 50 TO 100 mA WILL CHARGE THE CELLS IN ABOUT 5 TO 8 HOURS.

D1 PREVENTS THE NiCd CELLS FROM DISCHARGING THROUGH THE SOLAR CELLS.

SOLAR BATTERY CHARGER TIPS

1. NEVER EXCEED THE RECOMMENDED CHARGE RATE FOR A STORAGE CELL.

2. INCREASED CURRENT REDUCES CHARGING TIME. CHECK THE BATTERY'S SPECIFICATIONS TO FIND THE MAXIMUM ALLOWABLE CURRENT.

3. DO NOT USE A SOLAR ARRAY THAT DELIVERS TOO MUCH CURRENT TO THE CELLS BEING CHARGED.

4. SEVERAL TIMES A DAY REORIENT A SOLAR PANEL SO IT FACES THE SUN.

5. SOLAR CELLS WORK BEST WHEN COOL. AVOID PLACING A SOLAR PANEL ON SURFACES THAT BECOME HOT IN SUNLIGHT, SUCH AS PAVEMENT OR DARK PAINTED METAL.

6. STORAGE BATTERIES CAN BE MOUNTED ON THE BACK SIDE OF A SOLAR PANEL. BUT THEY WORK BEST WHEN KEPT IN A COOLER LOCATION WHILE BEING CHARGED.

MONITORING A SOLAR CHARGER

YOU CAN MEASURE THE CURRENT FROM A SOLAR PANEL WITH A MULTIMETER.

1. CONNECT A MULTIMETER SET TO MEASURE CURRENT BETWEEN THE BLOCKING DIODE AND THE BATTERY BEING CHARGED. BE SURE TO OBSERVE POLARITY, OR ...

2. CONNECT A 1-OHM POWER RESISTOR BETWEEN THE BLOCKING DIODE AND THE BATTERY BEING CHARGED. USE A MULTIMETER TO MEASURE THE VOLTAGE (V) ACROSS THE RESISTOR (R). FROM OHM'S LAW, CURRENT EQUALS V/R OR, IN THIS CASE, V.

TAKE A SOLAR CELL INTO SPACE

SOLAR CELLS ARE SENSITIVE TO ONLY PART OF THE SOLAR SPECTRUM. THEREFORE A SOLAR CELL CAN NOT MEASURE THE POWER OF THE TOTAL AMOUNT OF SUNLIGHT AT THE TOP OF THE ATMOSPHERE (THE SOLAR CONSTANT), EVEN IF YOU COULD TAKE ONE THERE.

ACCORDING TO SOLAREX, A MAJOR SOLAR CELL MANUFACTURER, A SOLAR CELL PRODUCES ABOUT +14.6% MORE POWER IN SPACE THAN THE SAME CELL PRODUCES ON EARTH. LET'S CALL THIS PERFORMANCE INCREASE A SOLAR CELL'S SPACE EFFICIENCY.

YOU DON'T NEED TO BECOME AN ASTRONAUT TO DETERMINE HOW MUCH MORE POWER A SOLAR CELL WILL PRODUCE IN SPACE. THE METHOD DESCRIBED HERE WILL REVEAL A SOLAR CELL'S SPACE EFFICIENCY FROM EARTH. FOLLOW THESE STEPS:

1. MOUNT A SOLAR CELL AT THE END OF A PVC OR CARDBOARD TUBE:

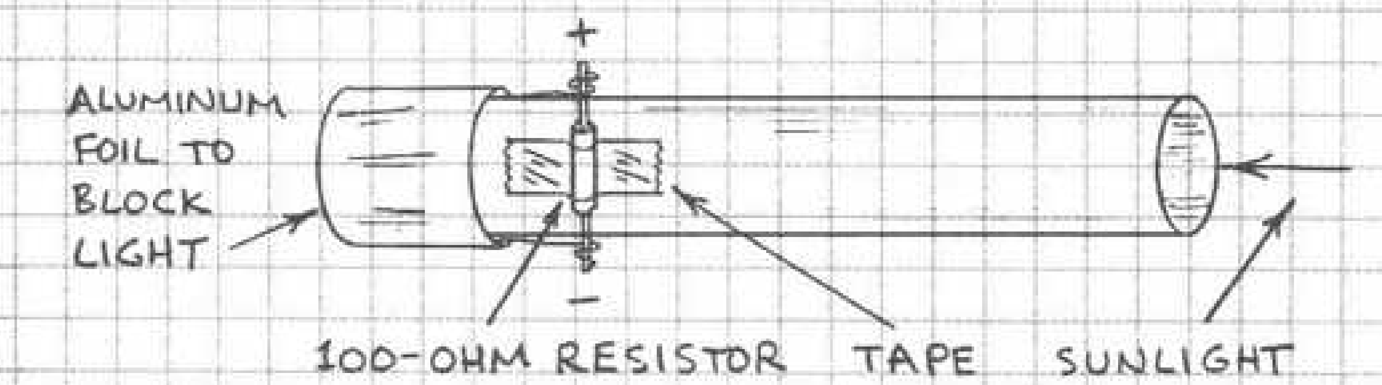


ℓ SHOULD BE AT LEAST 5 TIMES d.

USE DOUBLE SIDED TAPE TO ATTACH A BARE SOLAR CELL TO A THIN CARDBOARD DISK. USE DARK TAPE TO ATTACH THE CELL AND DISK TO THE END OF THE TUBE. ALTERNATIVELY, INSTALL THE SOLAR CELL IN A THIN, CLEAR PLASTIC BOX AND TAPE THE BOX TO THE END OF THE TUBE. IF THE SOLAR CELL IS LARGER THAN d, THE EXPOSED PORTION OF THE CELL MUST BE SHIELDED FROM LIGHT.

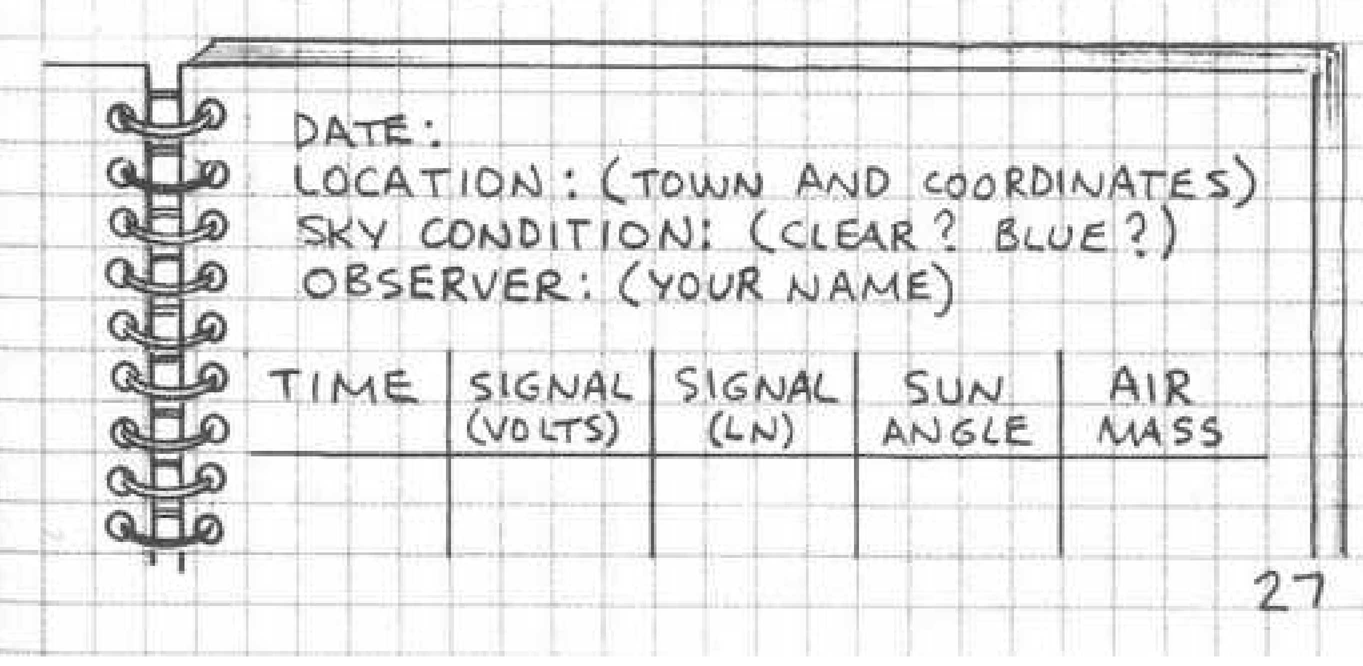
ONE WAY IS TO WRAP THE SOLAR CELL END OF THE TUBE WITH ALUMINUM FOIL. TAPE THE FOIL TO THE SIDE OF THE TUBE. BE SURE IT DOES NOT CONNECT TOGETHER OR SHORT THE SOLAR CELL LEADS.

2. CONNECT THE SOLAR CELL LEADS ACROSS A 100-OHM RESISTOR. TAPE THE RESISTOR TO THE SIDE OF THE TUBE AS SHOWN:



3. ON A CLEAR DAY MEASURE THE VOLTAGE ACROSS THE 100-OHM RESISTOR WHEN THE TUBE IS POINTED DIRECTLY AT THE SUN. THE TUBE IS PROPERLY POINTED WHEN ITS SHADOW DISAPPEARS AND WHEN THE VOLTAGE ACROSS THE 100-OHM RESISTOR REACHES A PEAK.

MAKE MEASUREMENTS FROM EARLY MORNING TO NOON OR FROM NOON TO LATE AFTERNOON. IF YOU DO NOT HAVE INTERNET ACCESS YOU WILL NEED TO MEASURE THE ANGLE OF THE SUN OVER THE HORIZON AT EACH MEASUREMENT. RECORD YOUR DATA IN A NOTEBOOK UNDER THESE HEADINGS:



DATE:
LOCATION: (TOWN AND COORDINATES)
SKY CONDITION: (CLEAR? BLUE?)
OBSERVER: (YOUR NAME)

TIME	SIGNAL (VOLTS)	SIGNAL (LN)	SUN ANGLE	AIR MASS

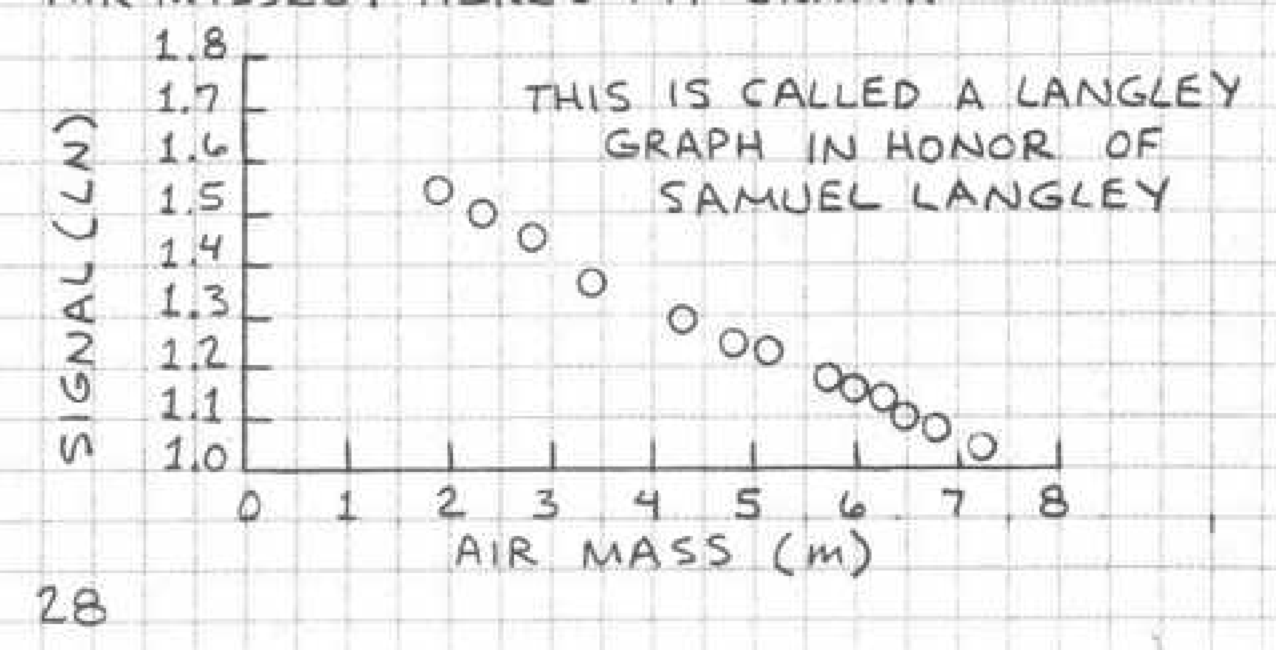
4. AIR MASS (m) IS THE THICKNESS OF THE ATMOSPHERE BETWEEN YOU AND THE SUN. $m = 1/\sin\theta$, WHERE θ IS THE ANGLE OF THE SUN ABOVE THE HORIZON. FIND m FOR EACH TIME YOU MADE A MEASUREMENT. USE THE SUN ANGLES YOU MEASURED. OR VISIT A SEARCH ENGINE ON THE WORLD WIDE WEB AND ENTER "SUN ANGLE CALCULATOR." CHECK THE WEB SITES AND SELECT A CALCULATOR YOU LIKE. FOLLOW THE INSTRUCTIONS TO FIND THE SUN ANGLE FOR EACH TIME. CALCULATE m FOR EACH ANGLE AND ENTER THE RESULTS IN YOUR NOTEBOOK.

5. USE THE LN KEY ON A SCIENTIFIC CALCULATOR TO CONVERT THE SIGNALS YOU MEASURED TO THEIR NATURAL LOGARITHMS. ENTER THE RESULTS IN YOUR NOTEBOOK. HERE ARE SOME OF MY RESULTS:

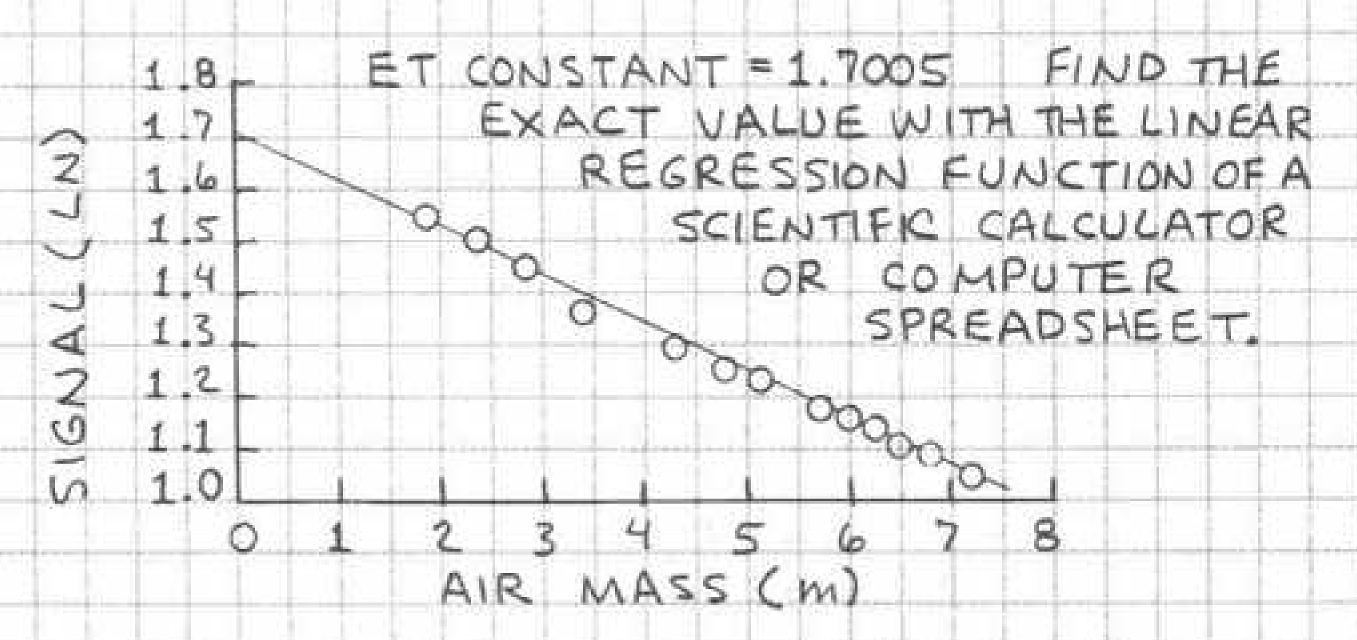
DATE: FEBRUARY 21, 1999
LOCATION: GERONIMO CREEK, TEXAS
SKY CONDITION: CLEAR AND BLUE
OBSERVER: FORREST M. MIMS III

TIME	SIGNAL (VOLTS)	SIGNAL (LN)	SUN ANGLE	AIR MASS
1550:20	4.60	1.5261	30.09°	1.99
1616:00	4.44	1.4907	25.39°	2.33

6. GRAPH THE LN OF THE SIGNALS AND THEIR AIR MASSES. HERE'S MY GRAPH:



IF THE SKY WAS CLEAR, THE POINTS BETWEEN AN AIR MASS OF ABOUT 2 TO 6 SHOULD FORM A STRAIGHT LINE. DRAW A LINE THROUGH THESE POINTS AND EXTEND IT TO THE Y (VERTICAL) AXIS OF THE GRAPH (AIR MASS = 0). THE LN OF THE SIGNAL THE SOLAR CELL WILL PRODUCE ABOVE THE ATMOSPHERE, THE CELL'S EXTRATERRESTRIAL (ET) CONSTANT, IS WHERE THE LINE CROSSES THE Y AXIS.

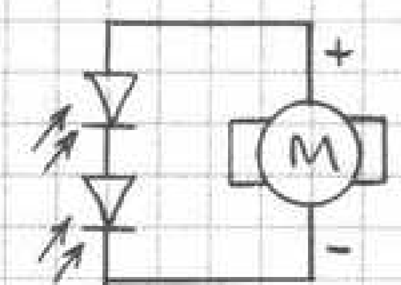


7. USE THE e^x KEY OF YOUR CALCULATOR TO CONVERT THE LN OF THE HIGHEST SIGNAL AT OR NEAR NOON AND THE ET CONSTANT TO THEIR ANTILOGS. DIVIDE THE ET CONSTANT BY THE NOON SIGNAL, SUBTRACT 1 AND ADD A % SIGN. THIS IS THE SOLAR CELL'S SPACE EFFICIENCY, THE INCREASE IN PERFORMANCE THE CELL WILL PROVIDE IN SPACE. THE SOLAR CELL I MEASURED HAS A SPACE EFFICIENCY OF +10.9%. THIS IS REASONABLY CLOSE TO THE +14.6% GIVEN BY SOLAREX. SOME OF THE DIFFERENCE IS BECAUSE THE LANGLEY METHOD WORKS BEST WITH A NARROW BAND OF WAVELENGTHS AND A SOLAR CELL DETECTS FROM ABOUT 400 TO 1100 NANOMETERS. DIFFERENCES ARE ALSO CAUSED BY DIFFERING AMOUNTS OF WATER VAPOR AND HAZE WHEN THE TESTS WERE CONDUCTED. WATER VAPOR IS ESPECIALLY IMPORTANT SINCE IT ABSORBS SOME NEAR INFRARED TO WHICH SOLAR CELLS ARE VERY SENSITIVE.

SOLAR POWERED MOTORS

SMALL DC MOTORS CAN BE POWERED BY SOLAR CELLS. SOME MOTORS REQUIRE ONLY A SINGLE CELL AND BRIGHT SUNLIGHT. MOST REQUIRE AN ARRAY OF SOLAR CELLS.

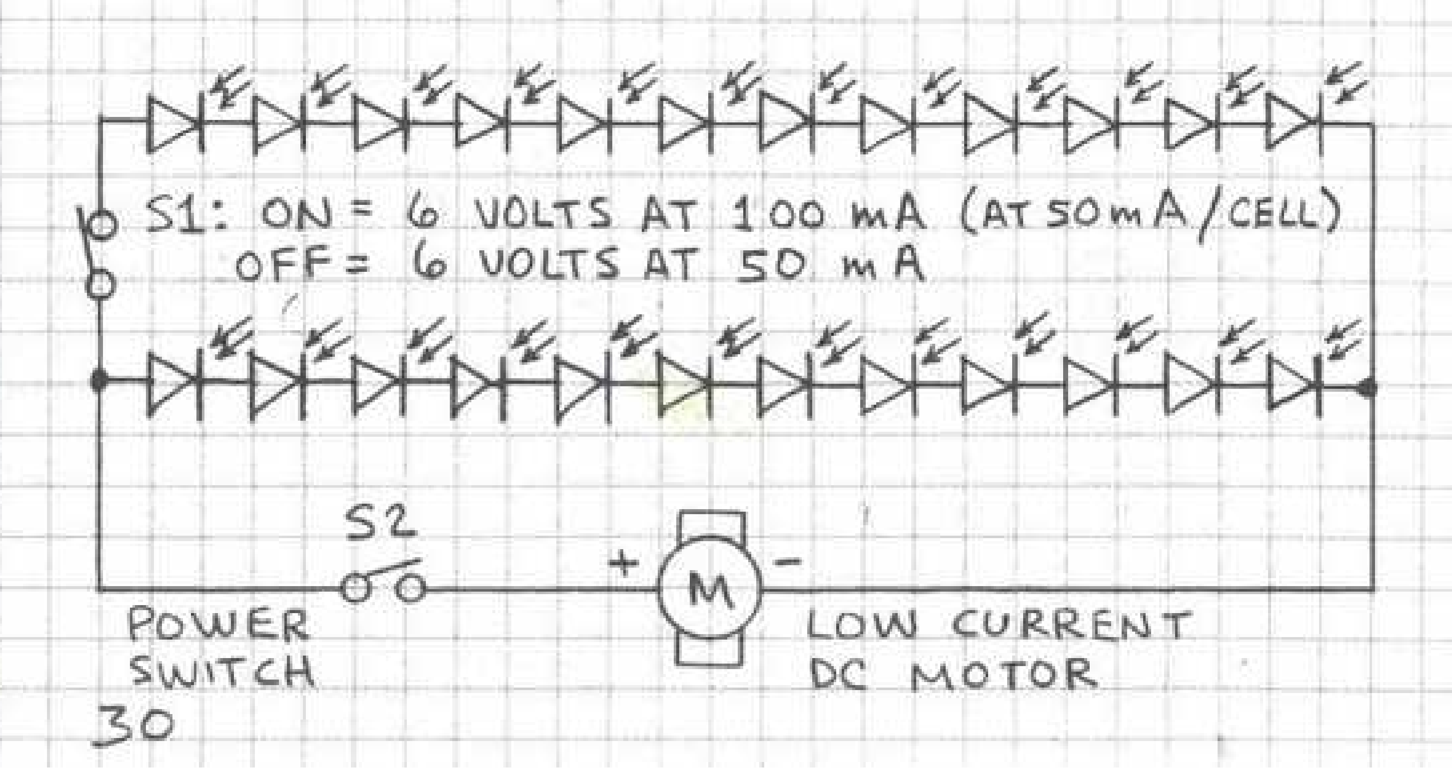
BASIC SOLAR POWERED MOTOR



A SINGLE SOLAR CELL GENERATES ENOUGH CURRENT TO POWER MOST SMALL DC MOTORS. ADD CELLS IN SERIES IF MORE VOLTAGE IS REQUIRED.

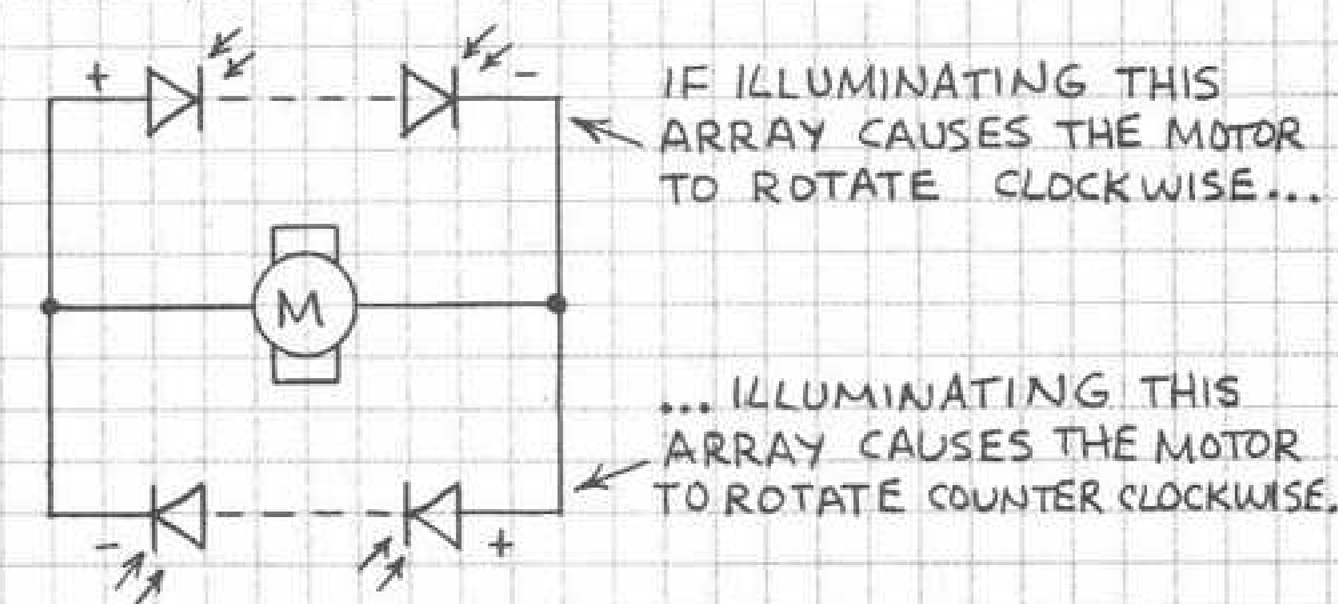
HIGHER POWER SOLAR MOTOR

A SOLAR CELL ARRAY THAT POWERS A MOTOR ON A BRIGHT SUMMER DAY MAY NOT PROVIDE ADEQUATE POWER DURING WINTER. THIS CIRCUIT FEATURES TWO SERIES ARRAYS CONNECTED IN PARALLEL TO PROVIDE DOUBLE THE CURRENT PRODUCED BY A SINGLE ARRAY. IF IDENTICAL 0.5 VOLT CELLS ARE USED AND IF EACH PRODUCES 50mA IN BRIGHT SUNLIGHT, THEN THIS ARRAY WILL PROVIDE 6 VOLTS (12 CELLS × 0.5 VOLT) AND 100 mA.



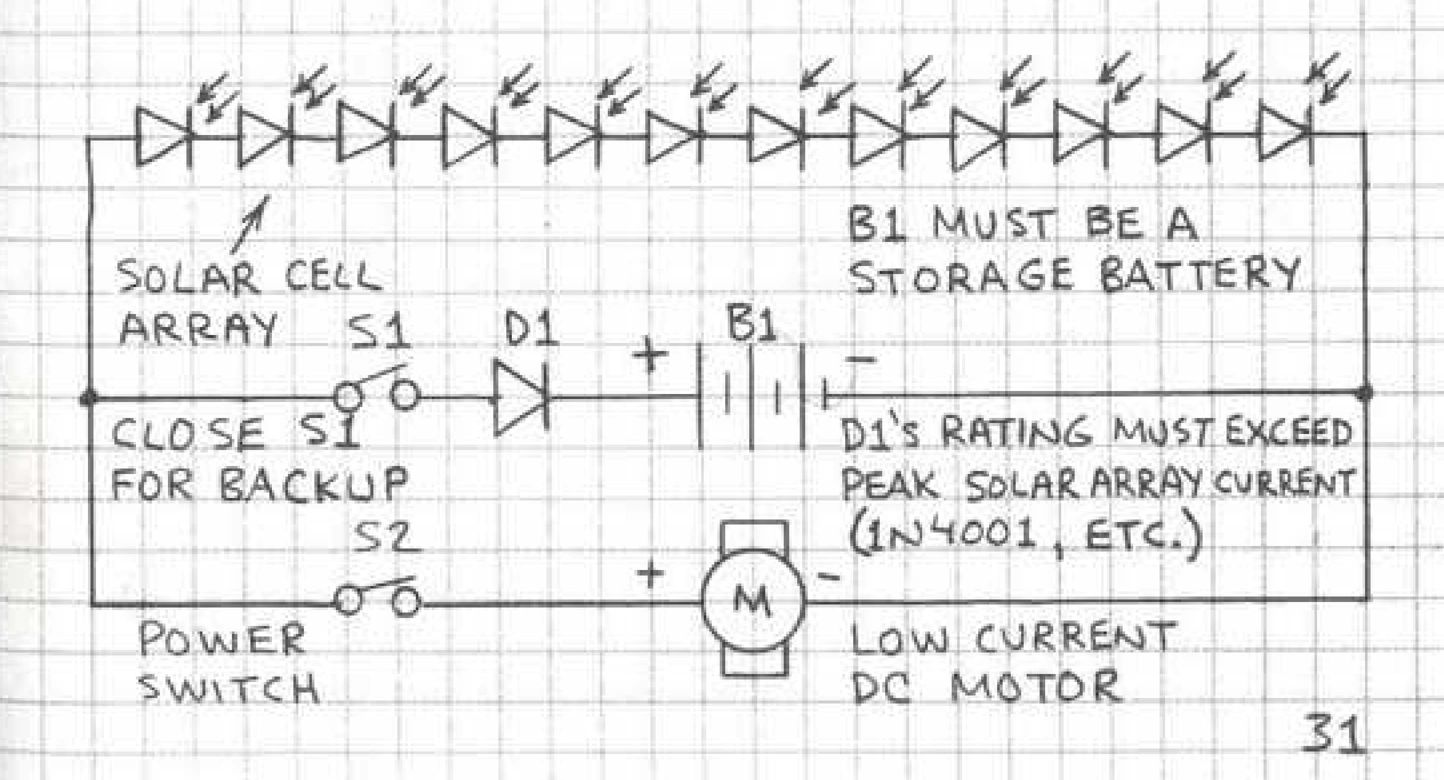
REVERSIBLE SOLAR MOTOR

A REVERSIBLE SOLAR POWERED MOTOR HAS APPLICATIONS IN ROBOTICS AND TRACKING THE SUN. THE ROTATION OF THE MOTOR BELOW IS CONTROLLED BY WHICH OF TWO SOLAR ARRAYS IS ILLUMINATED. WHEN BOTH ARRAYS ARE EQUALLY ILLUMINATED, THE MOTOR DOES NOT ROTATE.



SOLAR MOTOR WITH BATTERY BACKUP

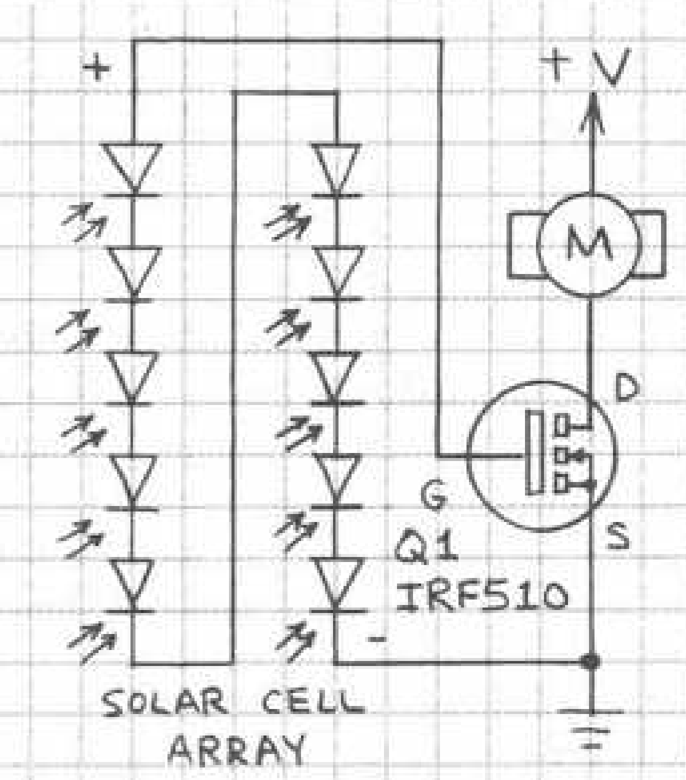
EVEN A BRIEF INTERRUPTION OF DIRECT SUNLIGHT WILL SLOW OR EVEN STOP A SOLAR POWERED MOTOR. A STORAGE BATTERY CONNECTED ACROSS THE MOTOR'S SOLAR CELL ARRAY WILL PROVIDE BACKUP POWER.



SOLAR ACTUATED MOTORS

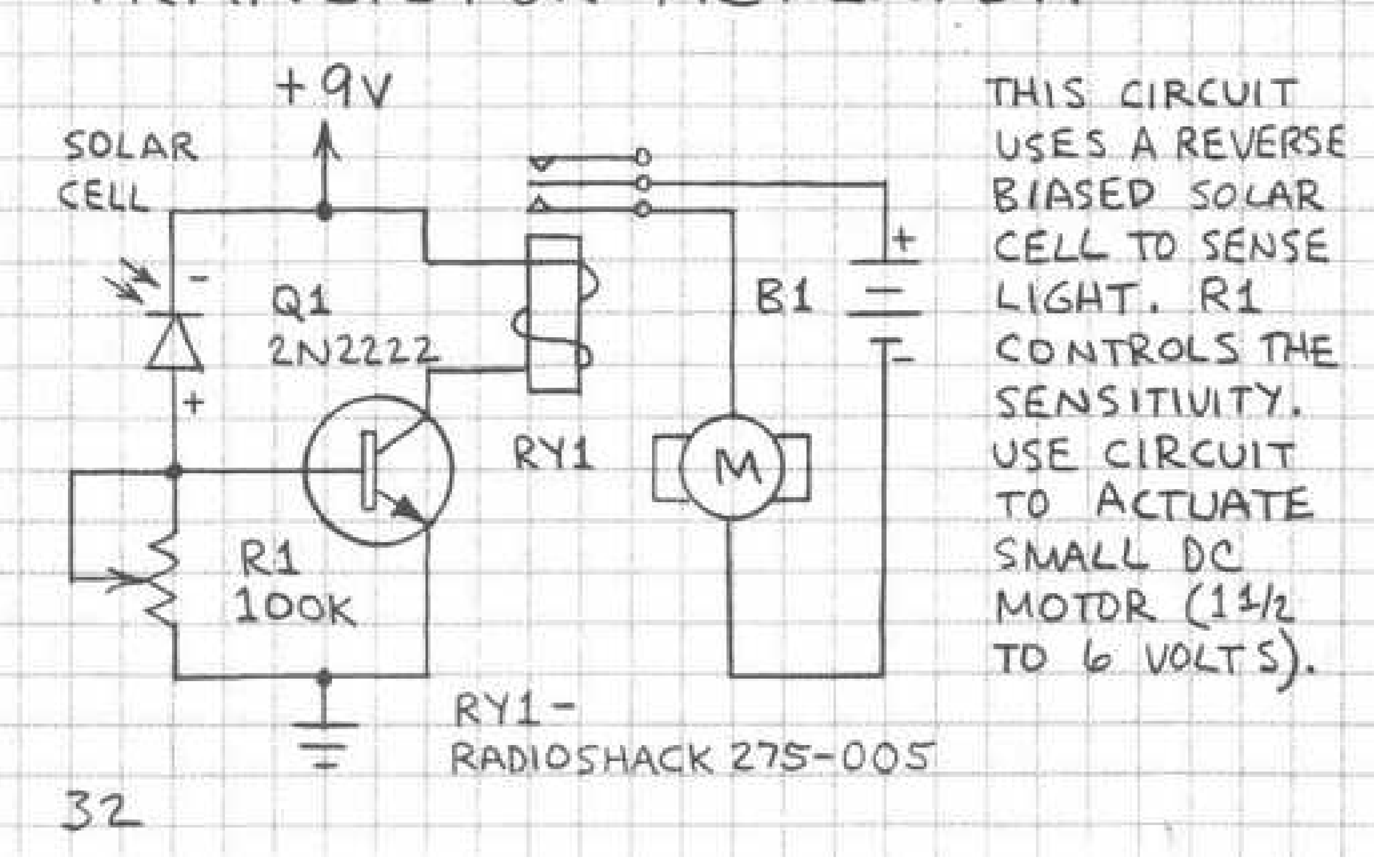
SOLAR CELLS HAVE MANY APPLICATIONS IN ROBOTICS AND CONTROL. THE CIRCUITS SHOWN HERE SWITCH SMALL DC MOTORS ON OR OFF WITH SUNLIGHT. SOME ARE SO SENSITIVE THEY CAN BE TRIGGERED WITH A SMALL FLASHLIGHT OR LASER POINTER.

POWER FET ACTUATOR (1)



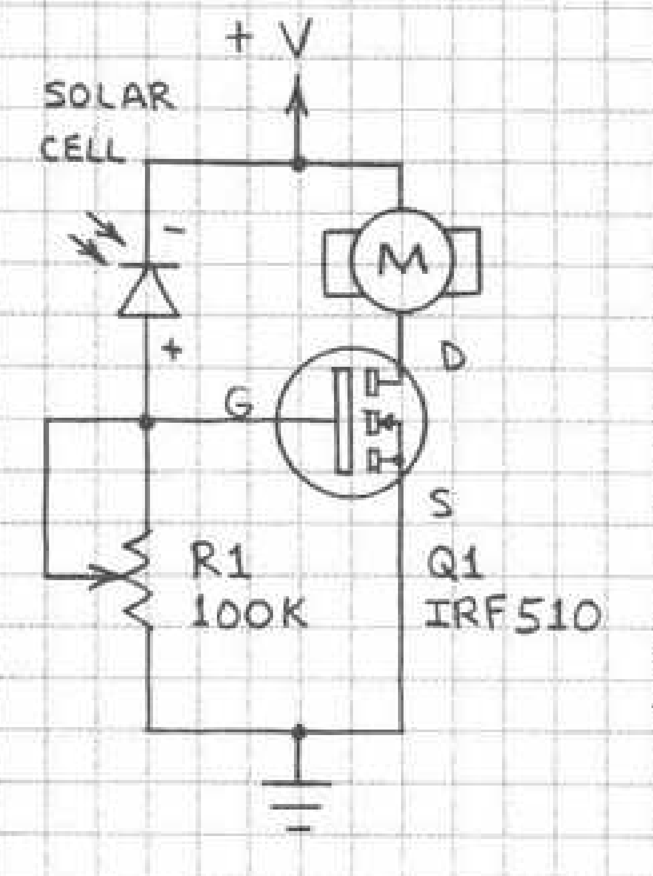
THIS CIRCUIT WILL DRIVE A SMALL DC MOTOR WHEN THE IRF510 POWER MOSFET IS SWITCHED ON WITH ABOUT 4 VOLTS FROM A SOLAR CELL ARRAY. THE IRF510 CAN DRIVE A MOTOR THAT CONSUMES UP TO 2 AMPS. +V SHOULD NOT EXCEED THE MOTOR'S RATING.

TRANSISTOR ACTUATOR



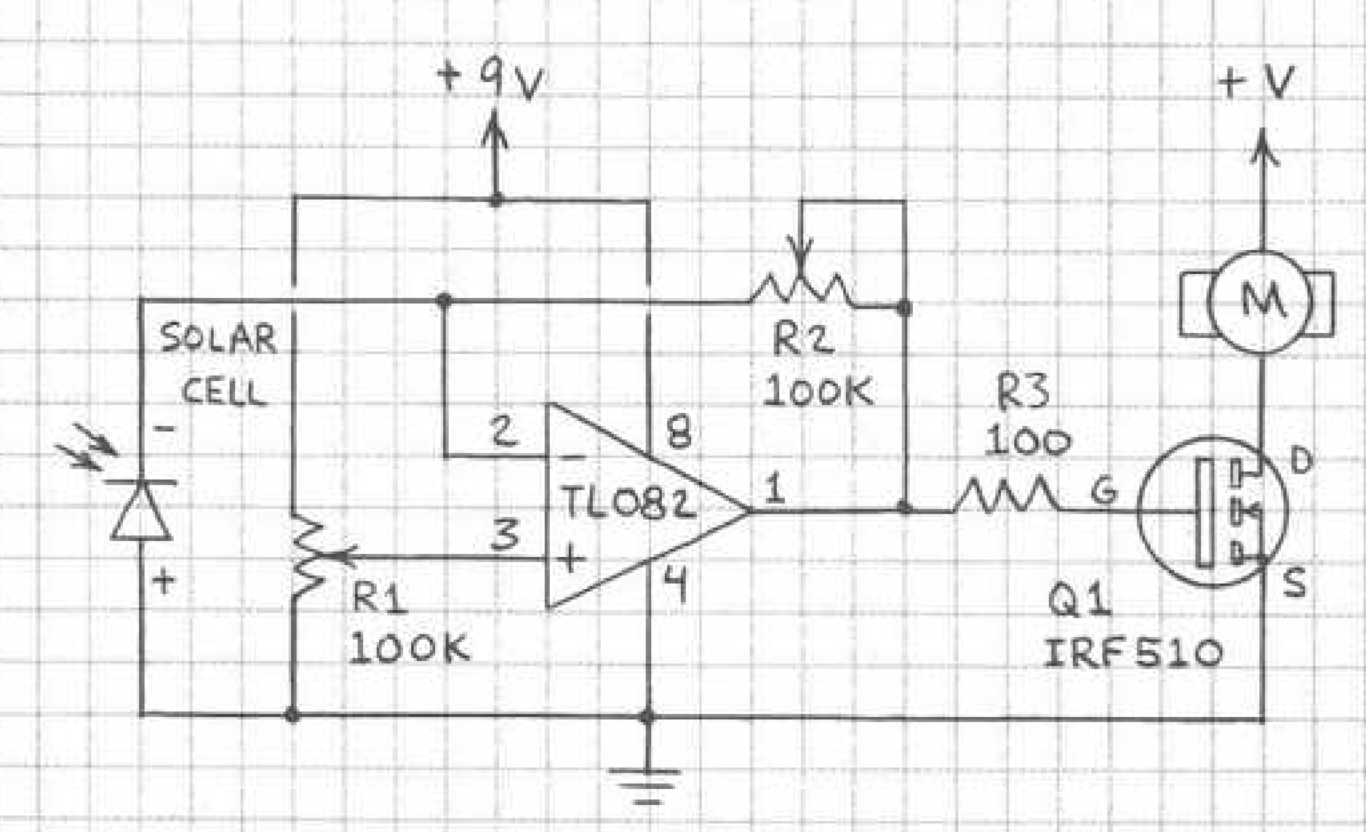
THIS CIRCUIT USES A REVERSE BIASED SOLAR CELL TO SENSE LIGHT. R1 CONTROLS THE SENSITIVITY. USE CIRCUIT TO ACTUATE SMALL DC MOTOR (1 1/2 TO 6 VOLTS).

POWER FET ACTUATOR (2)



THIS CIRCUIT WILL DRIVE A SMALL DC MOTOR WHEN THE IRF510 POWER MOSFET IS SWITCHED ON BY THE VOLTAGE DIVIDER FORMED BY THE SOLAR CELL AND R1. ADJUST R1 TO CONTROL SENSITIVITY. THE IRF510 WILL DRIVE A MOTOR THAT CONSUMES UP TO 2 AMPERES. +V SHOULD NOT EXCEED THE MOTOR'S RATING. USE SUNLIGHT, FLASHLIGHT OR LASER POINTER.

OP AMP - POWER FET ACTUATOR

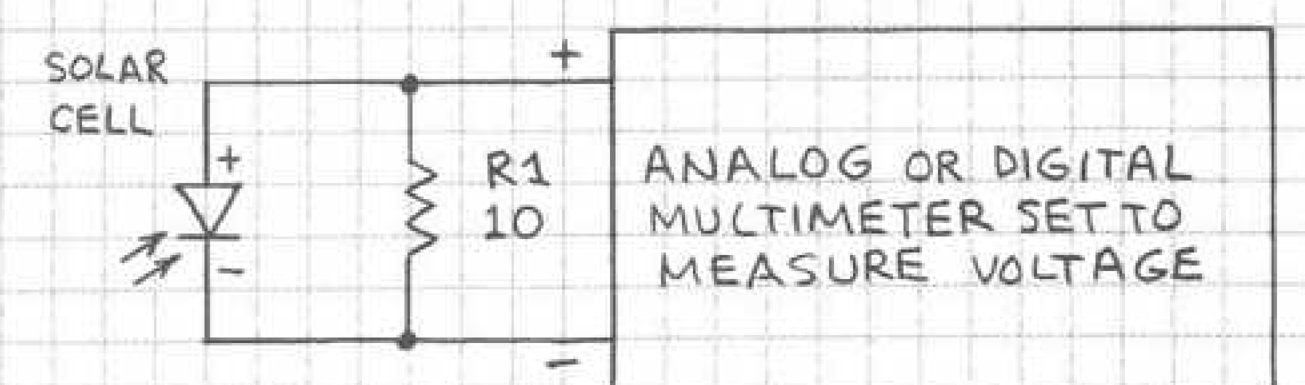


THIS CIRCUIT ALSO SWITCHES A SMALL DC MOTOR WITH AN IRF510 POWER MOSFET. ADDITIONAL FLEXIBILITY IS PROVIDED BY THE TL082 OP AMP. R1 CONTROLS THE SWITCHING THRESHOLD AND R2 CONTROLS THE GAIN. +V SHOULD NOT EXCEED THE MOTOR'S RATING.

SOLAR CELL LIGHT METERS

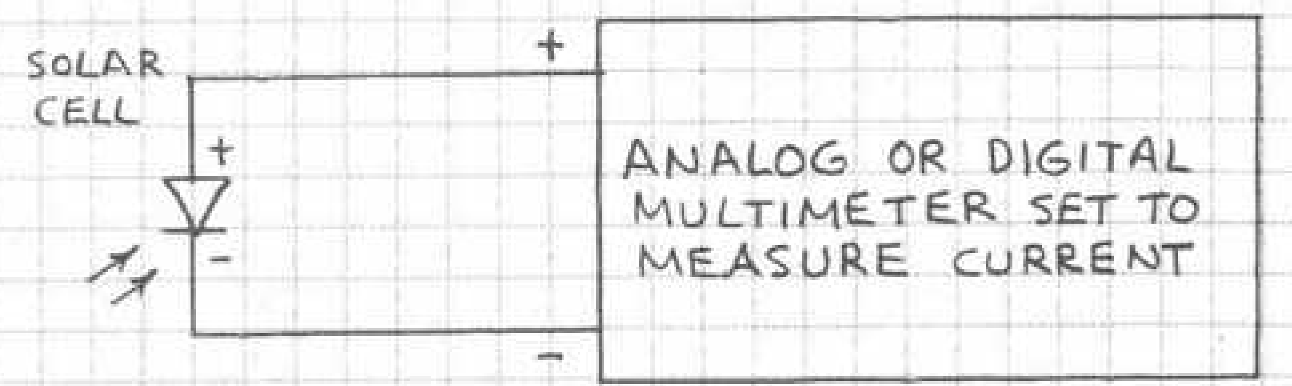
THE PHOTOCURRENT FROM A SILICON SOLAR CELL IS LINEAR WITH RESPECT TO LIGHT INTENSITY. THIS MEANS SOLAR CELLS MAKE EXCELLENT SENSORS FOR LIGHT METERS. THE APPLICATIONS SHOWN BELOW ARE FOR LIGHT METERS MADE FROM A SOLAR CELL AND A RADIOSHACK MULTITESTER.

LIGHT METER (VOLTAGE TYPE)



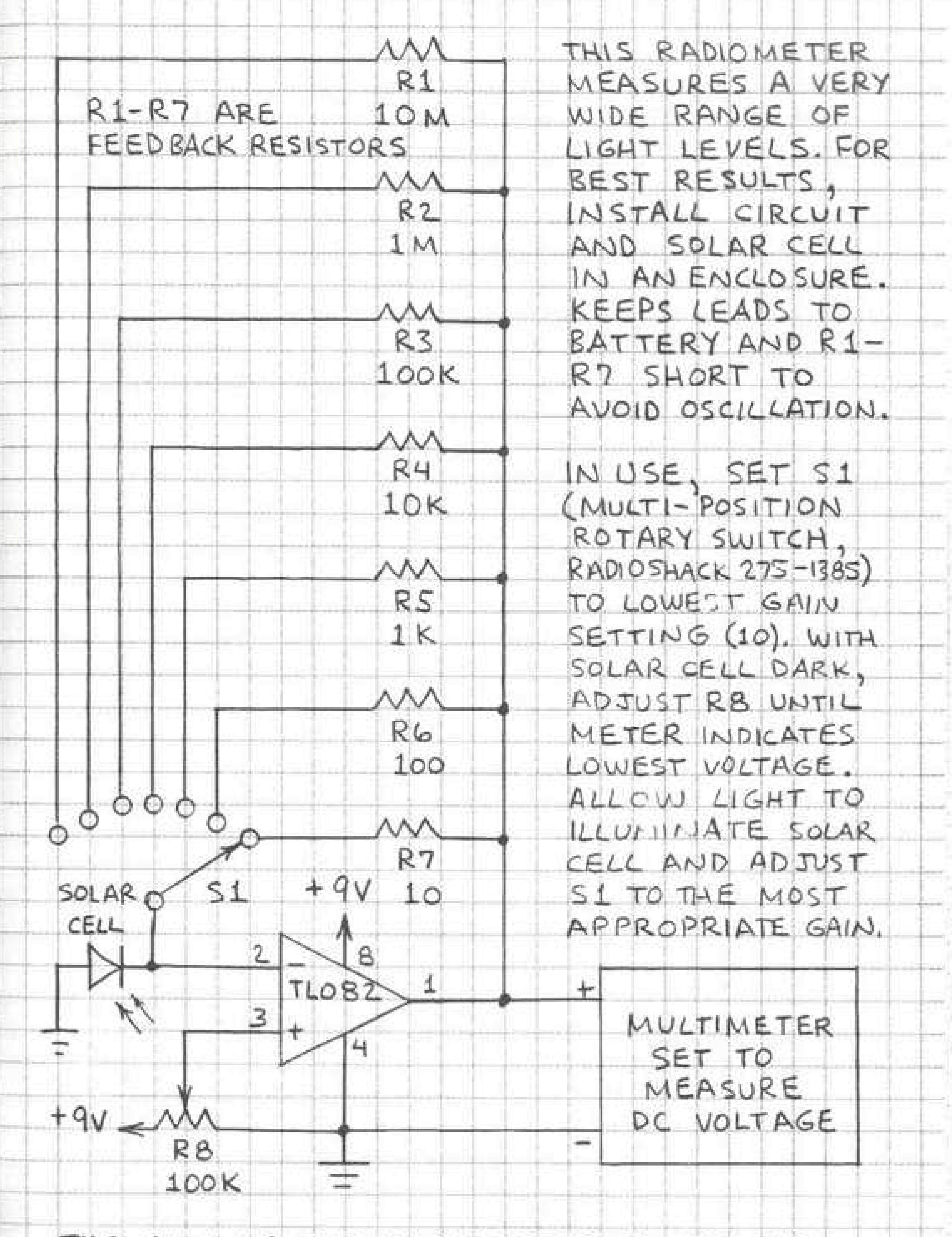
THE VOLTAGE PRODUCED BY A SOLAR CELL IS NOT LINEAR WITH RESPECT TO LIGHT INTENSITY. THIS ARRANGEMENT MEASURES THE PHOTOCURRENT (I_P) FROM A SOLAR CELL, WHICH IS LINEAR. FROM OHM'S LAW, THE CURRENT THROUGH A RESISTOR IS V/R. IF R1 IS 10 OHMS AND THE VOLTAGE ACROSS R1 IS 0.42 VOLT, THEN $I_P = 0.42 / 10$ OR 0.042 AMPERE (42 mA).

LIGHT METER (CURRENT TYPE)



THIS ARRANGEMENT DIRECTLY MEASURES SOLAR CELL PHOTOCURRENT.

SOLAR CELL RADIOMETER



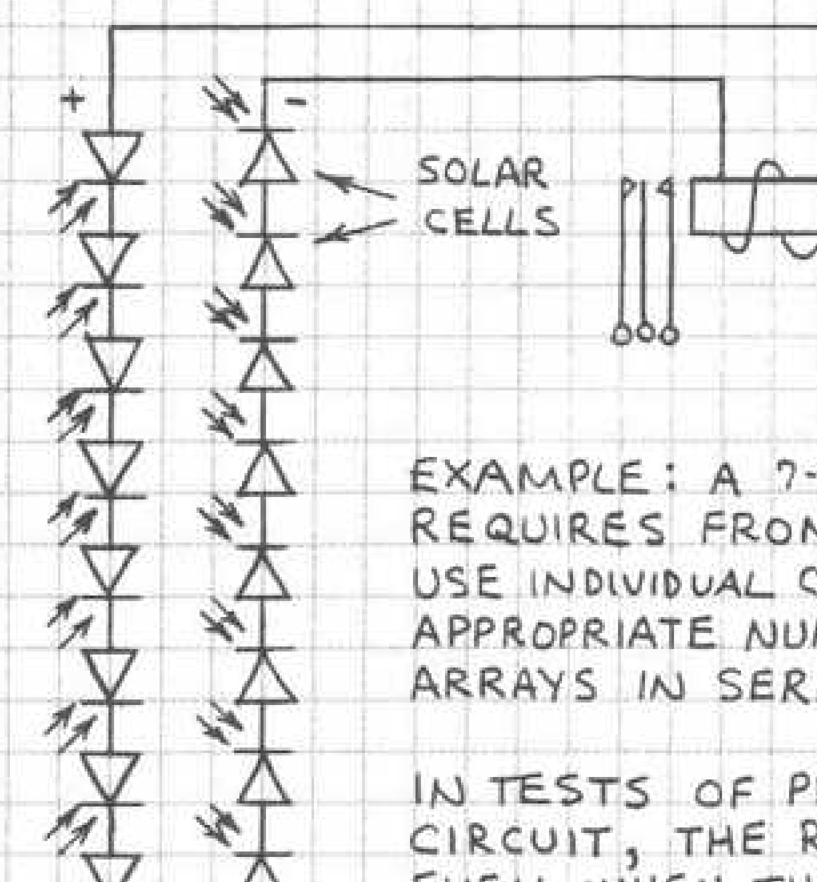
THIS RADIOMETER MEASURES A VERY WIDE RANGE OF LIGHT LEVELS. FOR BEST RESULTS, INSTALL CIRCUIT AND SOLAR CELL IN AN ENCLOSURE. KEEPS LEADS TO BATTERY AND R1-R7 SHORT TO AVOID OSCILLATION.

IN USE, SET S1 (MULTI-POSITION ROTARY SWITCH, RADIOSHACK 275-1385) TO LOWEST GAIN SETTING (10). WITH SOLAR CELL DARK, ADJUST R8 UNTIL METER INDICATES LOWEST VOLTAGE. ALLOW LIGHT TO ILLUMINATE SOLAR CELL AND ADJUST S1 TO THE MOST APPROPRIATE GAIN.

THE GAIN OF THE RADIOMETER EQUALS THE FEEDBACK RESISTANCE (R1-R7). THUS WHEN R4 IS SELECTED, THE RADIOMETER MULTIPLIES THE SOLAR CELL PHOTOCURRENT 10,000 TIMES.

SUNLIGHT ACTUATED RELAY

A SERIES ARRANGEMENT OF SILICON SOLAR CELLS WILL ACTIVATE A RELAY. THE SOLAR CELL ARRAY MUST PROVIDE SUFFICIENT VOLTAGE AND CURRENT TO OPERATE THE RELAY. THE ARRAY SHOWN HERE WILL PULL IN A LOW CURRENT RELAY WITH A 7-TO 9-VOLT COIL.

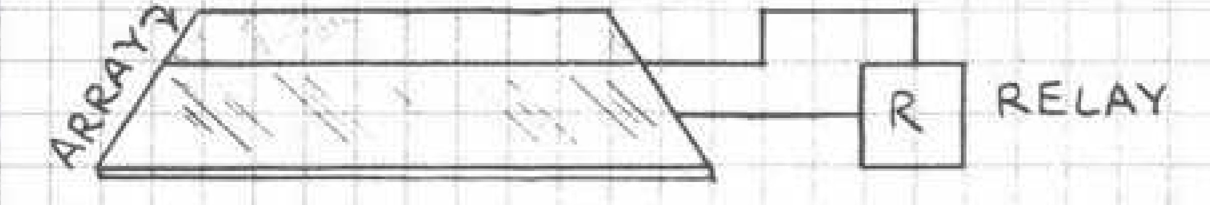


7-TO 9-VOLT LOW CURRENT RELAY (RADIOSHACK 275-005 OR SIMILAR)

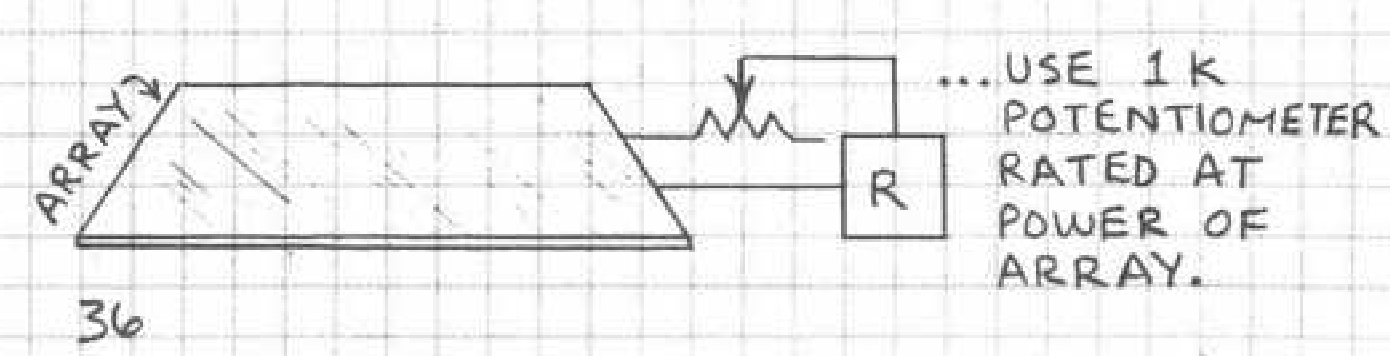
EXAMPLE: A 7-TO 9-VOLT RELAY REQUIRES FROM 14 TO 18 CELLS. USE INDIVIDUAL CELLS OR CONNECT APPROPRIATE NUMBER OF SOLAR ARRAYS IN SERIES.

IN TESTS OF PROTOTYPE CIRCUIT, THE RELAY PULLED IN EVEN WHEN THE ARRAY WAS TILTED SOMEWHAT AWAY FROM SUN.

SENSITIVITY ADJUSTMENTS:



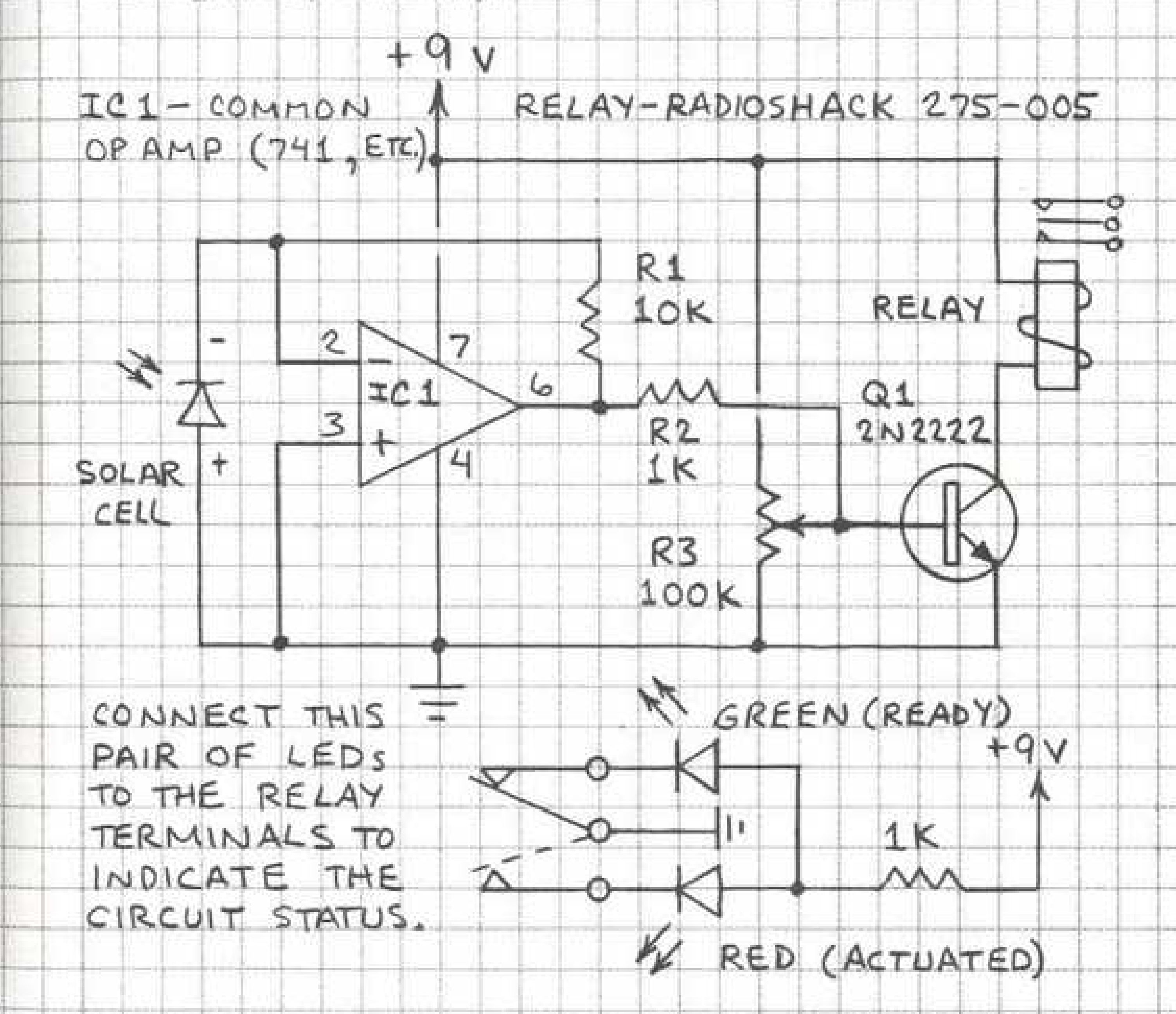
BLOCK PART OF THE ARRAY WITH AN OPAQUE COVER TO REDUCE SENSITIVITY, OR...



...USE 1K POTENTIOMETER RATED AT POWER OF ARRAY.

LIGHT ACTUATED RELAY

A SOLAR CELL GENERATES A PHOTOCURRENT WHEN ILLUMINATED. THE CIRCUIT SHOWN HERE AMPLIFIES THE CURRENT FROM A SINGLE SOLAR CELL AND DRIVES A RELAY. THIS CIRCUIT WILL WORK WITH A VERY SMALL SOLAR CELL AND WILL RESPOND TO VERY LOW LEVELS OF LIGHT.



WITH ROOM LIGHTS SUBDUED, ADJUST R3 UNTIL THE RED LED JUST STOPS GLOWING AND THE GREEN LED GLOWS. LIGHT FROM A FLASHLIGHT WILL TRIGGER THE CIRCUIT AND THE RED LED WILL GLOW. THE CIRCUIT WILL RESPOND TO AN LED, MATCH, CANDLE, DAYLIGHT AND A LASER POINTER. SINCE THE CIRCUIT RESPONDS TO MANY LIGHT SOURCES, NEVER USE IT TO CONTROL HAZARDOUS THINGS (MACHINERY, ETC.).

BREAK-BEAM DETECTION SYSTEMS

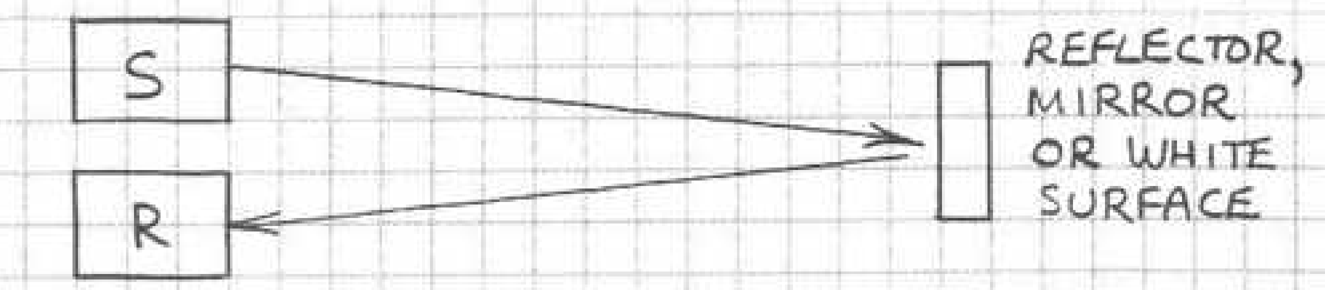
BREAK-BEAM DETECTION SYSTEMS DETECT EVERYTHING FROM ITEMS ON A CONVEYOR BELT AND SMOKE TO CUSTOMERS IN STORES AND BURGLARS. WHEN A LIGHT BEAM IS INTERRUPTED, THE SYSTEM SWITCHES AN ALARM, COUNTER OR LIGHT. HERE ARE SOME COMMON BREAK-BEAM CONFIGURATIONS:

IN-LINE MODE

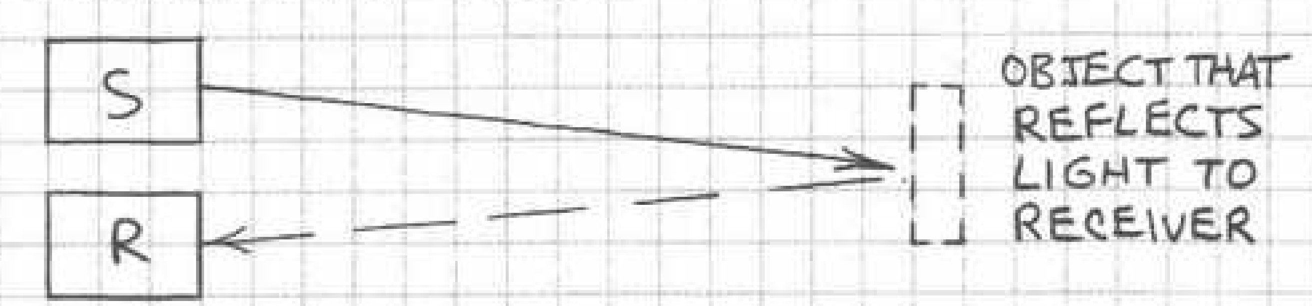
S → R

LIGHT SOURCE RECEIVER

REFLECTION MODE



PROXIMITY MODE



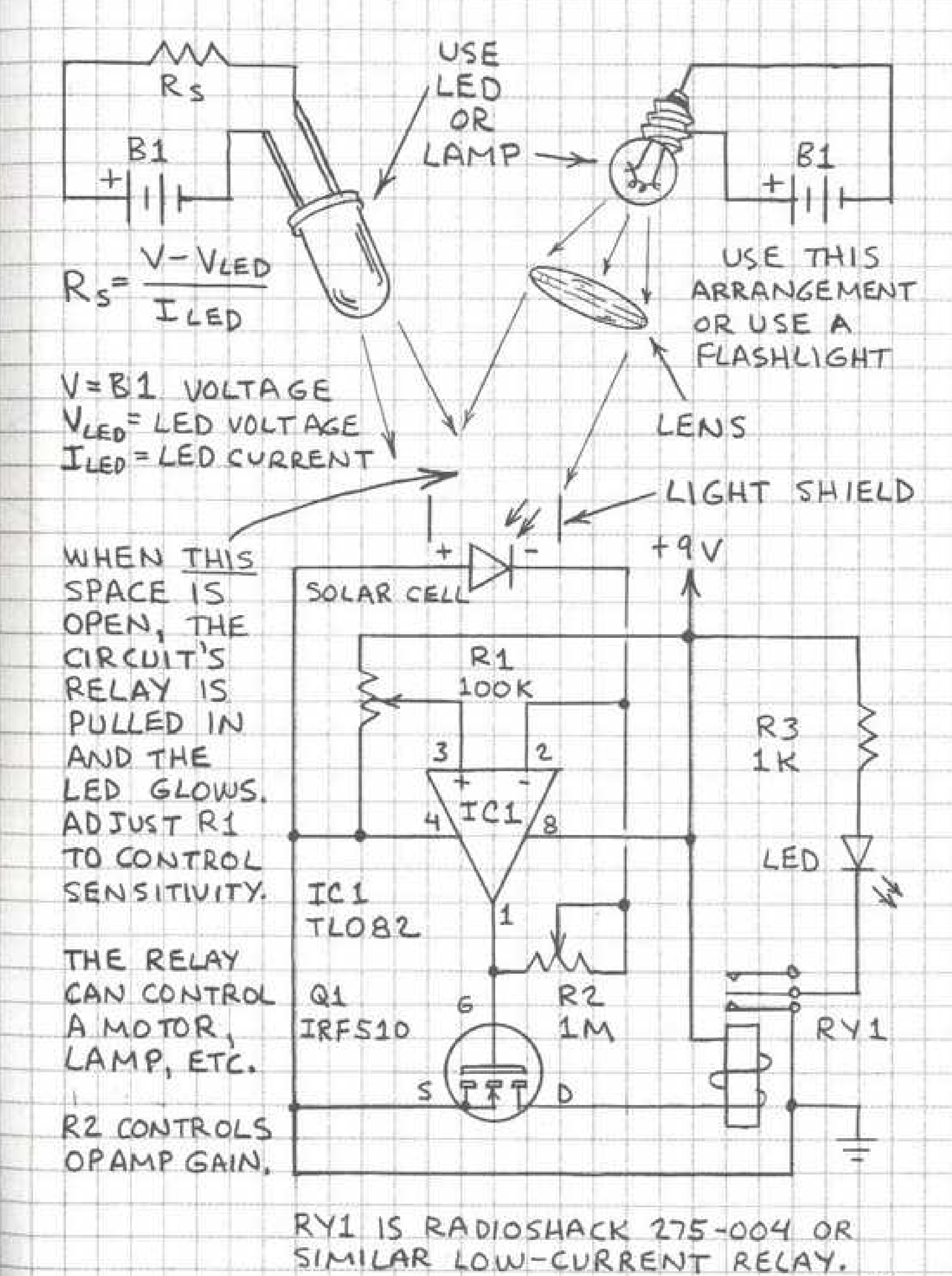
KINDS OF BREAK-BEAM SYSTEMS

STEADY STATE — THE LIGHT SOURCE IS A LAMP, LED OR SUNLIGHT. WHILE VERY SIMPLE, A STEADY-STATE SYSTEM CAN BE INTERFERED WITH BY AN OUTSIDE SOURCE.

PULSED — THE LIGHT IS A PULSED LED. A CAPACITOR BETWEEN THE SOLAR CELL AND THE RECEIVER BLOCKS INTERFERENCE FROM NON-PULSED OUTSIDE LIGHT SOURCES.

STEADY-STATE BREAK-BEAM SYSTEM

THIS SYSTEM PULLS IN A RELAY AND LIGHTS AN LED WHEN STEADY LIGHT ILLUMINATES THE SOLAR CELL.

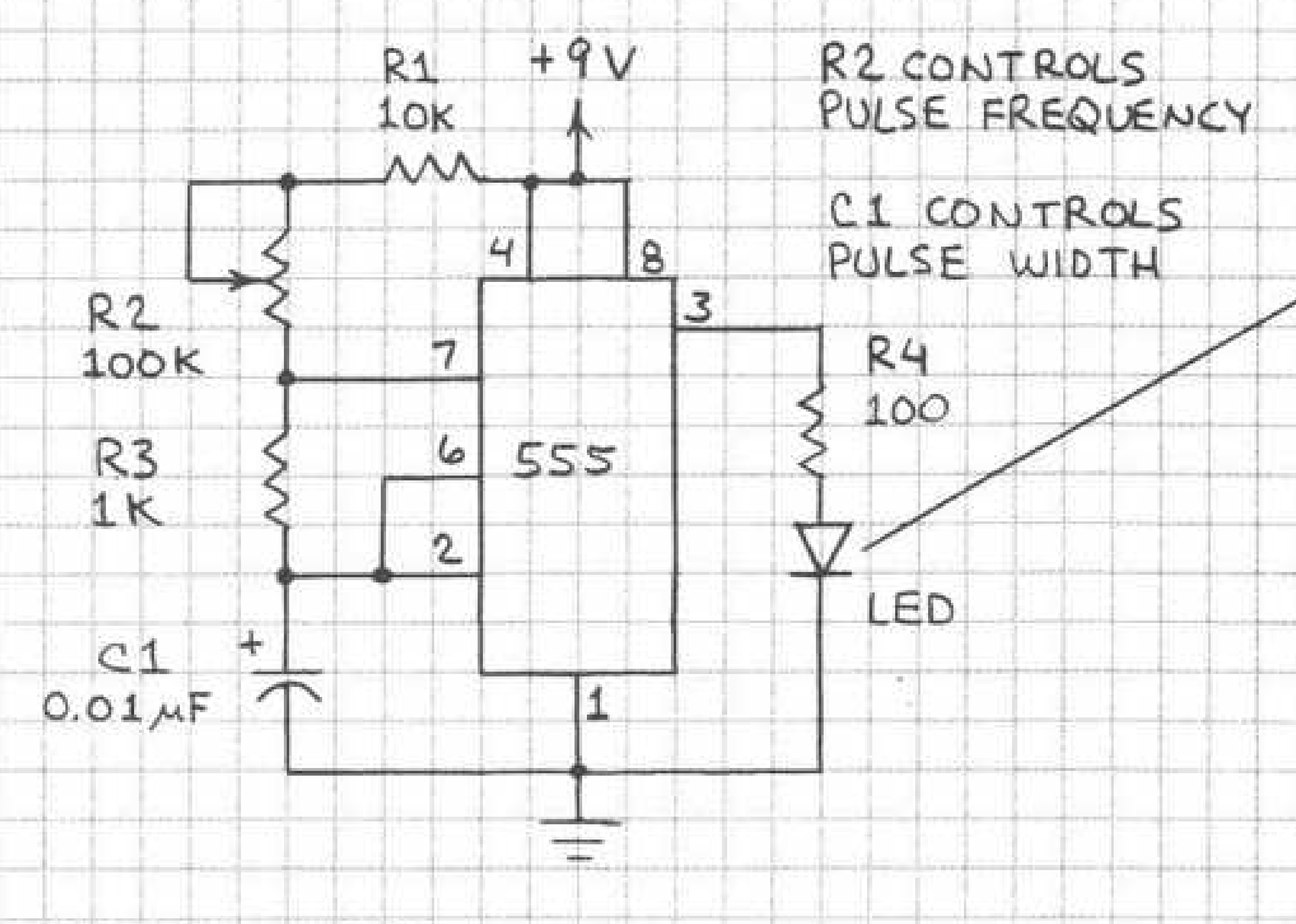


RY1 IS RADIOSHACK 275-004 OR SIMILAR LOW-CURRENT RELAY.

PULSED BREAK-BEAM SYSTEM

A PULSED BREAK-BEAM SYSTEM IS GENERALLY IMMUNE TO STEADY-STATE LIGHT SOURCES. THIS IS VERY IMPORTANT WHEN THE SYSTEM IS OPERATED IN THE PRESENCE OF ROOM LIGHTS OR WEAK SUNLIGHT. A SOLAR CELL RECEIVER FOR A PULSED BREAK-BEAM SYSTEM IS SHOWN ON THE FACING PAGE. SHOWN BELOW IS A 555 PULSED LED TRANSMITTER THAT WILL WORK WITH THIS RECEIVER.

PULSED BREAK-BEAM TRANSMITTER



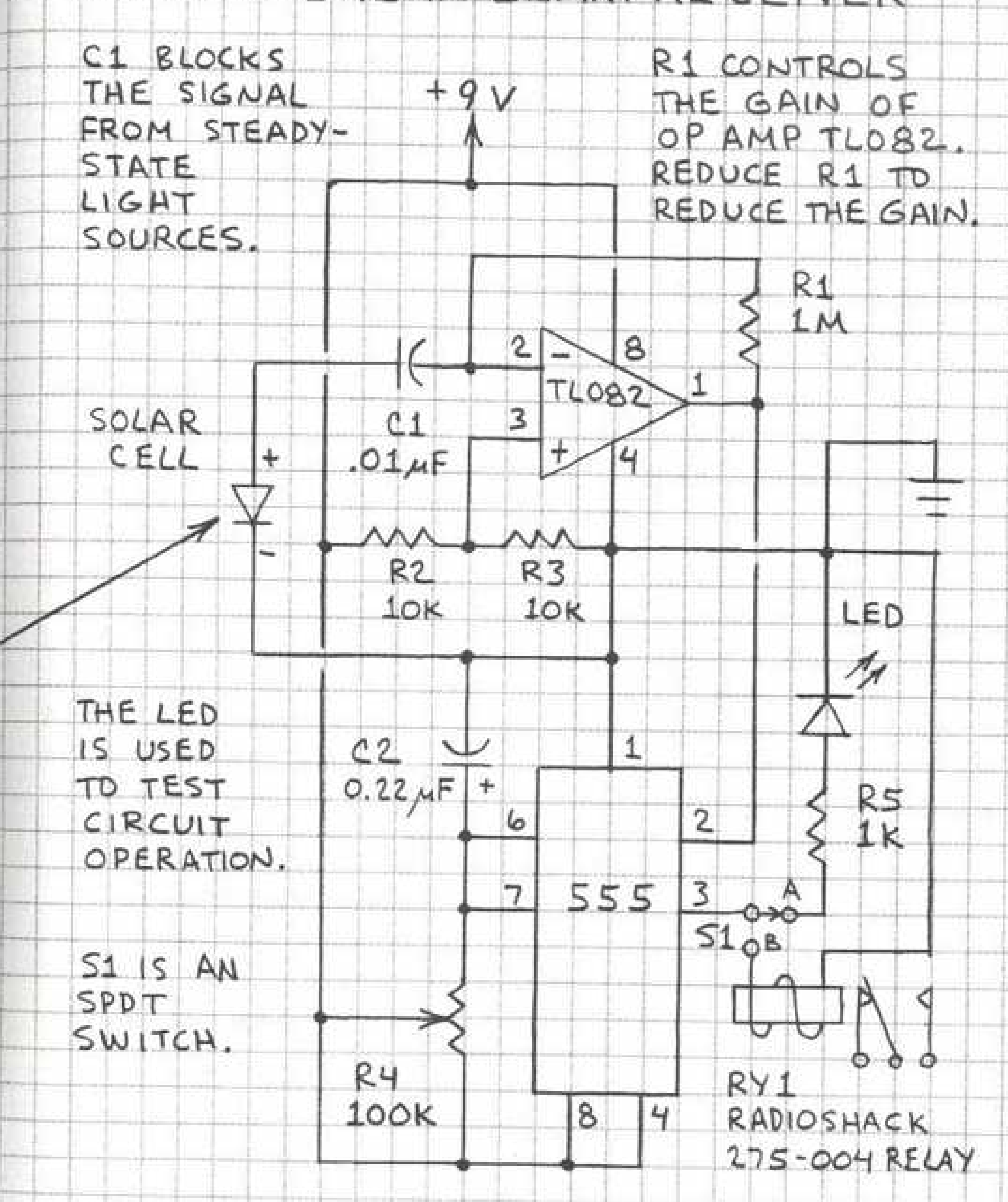
FOR BEST RESULTS:

1. USE AN INFRARED OR SUPER BRIGHT RED LED FOR MAXIMUM RANGE.

2. POWER THE TRANSMITTER AND RECEIVER FROM SEPARATE BATTERIES.

3. BE SURE THE BEAM FROM THE LED ILLUMINATES THE SOLAR CELL.

PULSED BREAK-BEAM RECEIVER

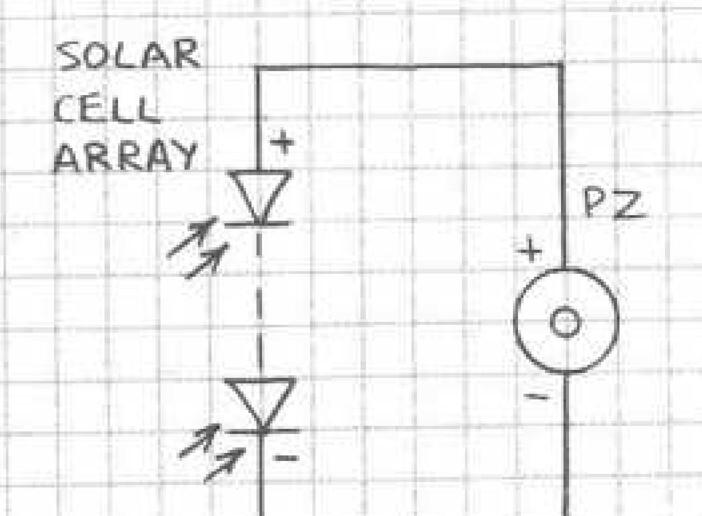


TO OPERATE, SWITCH S1 TO POSITION A. ADJUST R2 OF THE TRANSMITTER TO ITS MID-POINT. WHEN LIGHT FROM THE LED IS STRIKING THE SOLAR CELL, ADJUST R4 OF THE RECEIVER UNTIL THE RECEIVER'S LED SWITCHES ON. THE LED SHOULD SWITCH OFF WHEN THE TRANSMITTER LED IS POINTED AWAY FROM THE SOLAR CELL OR ITS LIGHT IS BLOCKED. SWITCH S1 TO B TO SELECT RELAY.

SUN POWERED TONE GENERATORS

THE CIRCUITS ON THIS AND THE FACING PAGE ARE POWERED SOLELY BY SUNLIGHT OR A BRIGHT LAMP. MOST PRODUCE A TONE OR BUZZ. ONE GENERATES A SOUND THAT SOUNDS MUCH LIKE A TICKING CLOCK.

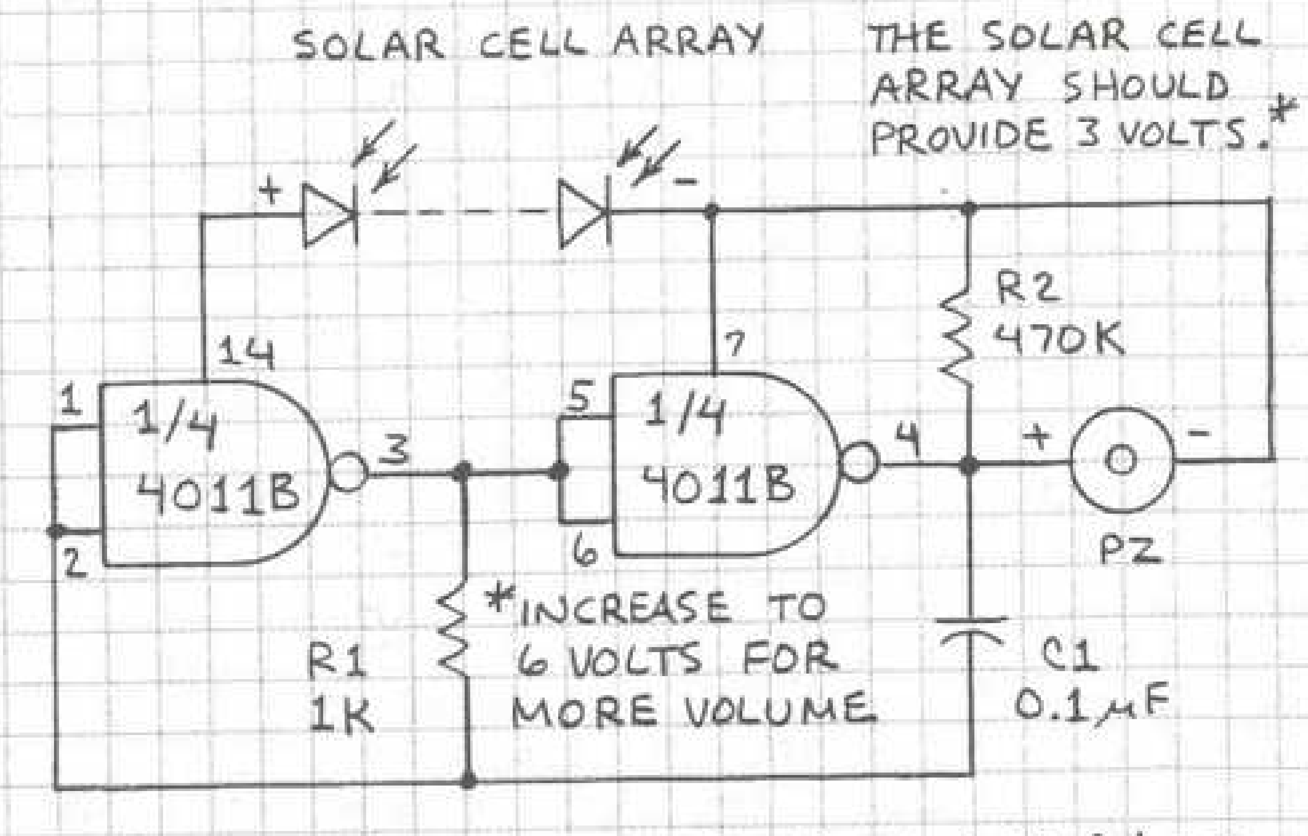
SOLAR POWERED PIEZO BUZZER



THE SOLAR ARRAY MUST PROVIDE SUFFICIENT VOLTAGE TO POWER THE PIEZO BUZZER. ANY PIEZO BUZZER CAN BE POWERED BY SUNLIGHT.

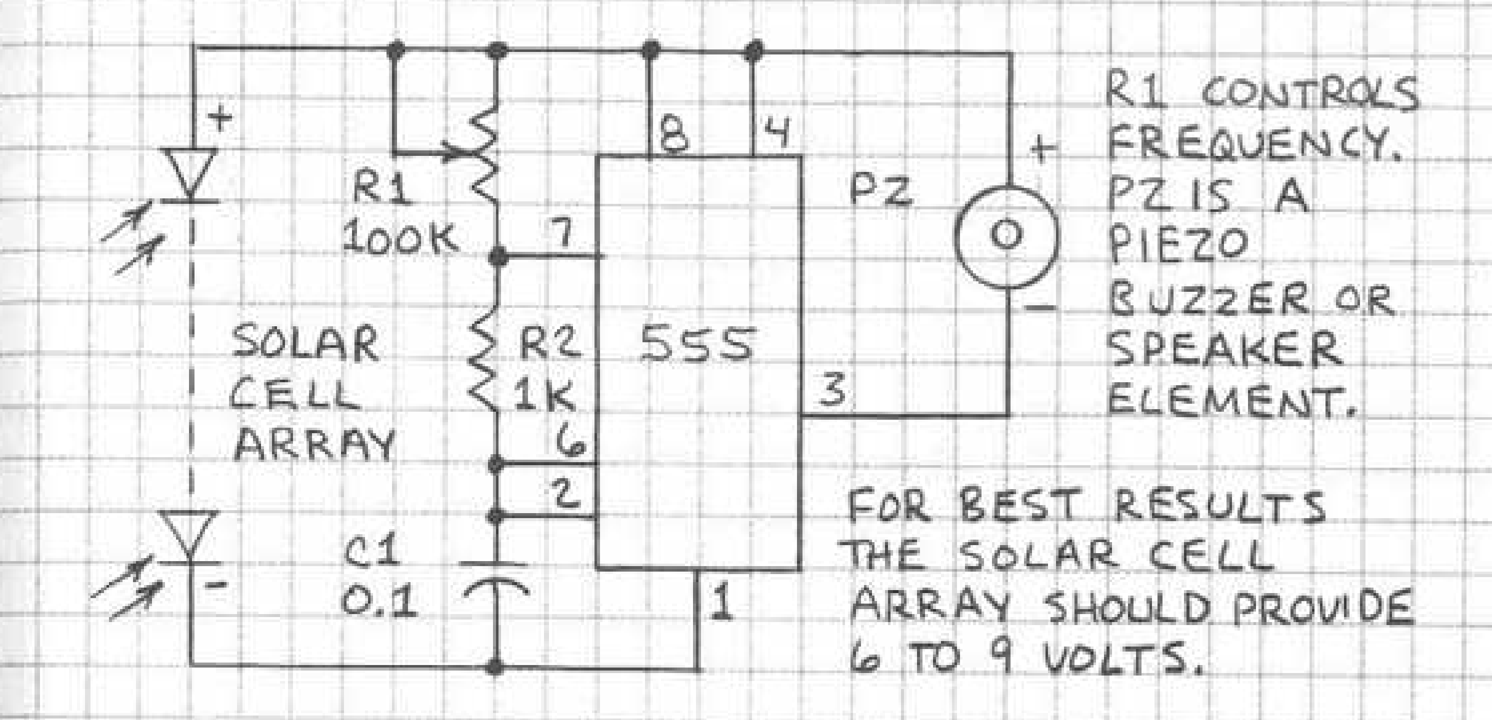
PZ IS A PIEZO BUZZER.

SOLAR POWERED DUAL-GATE OSCILLATOR

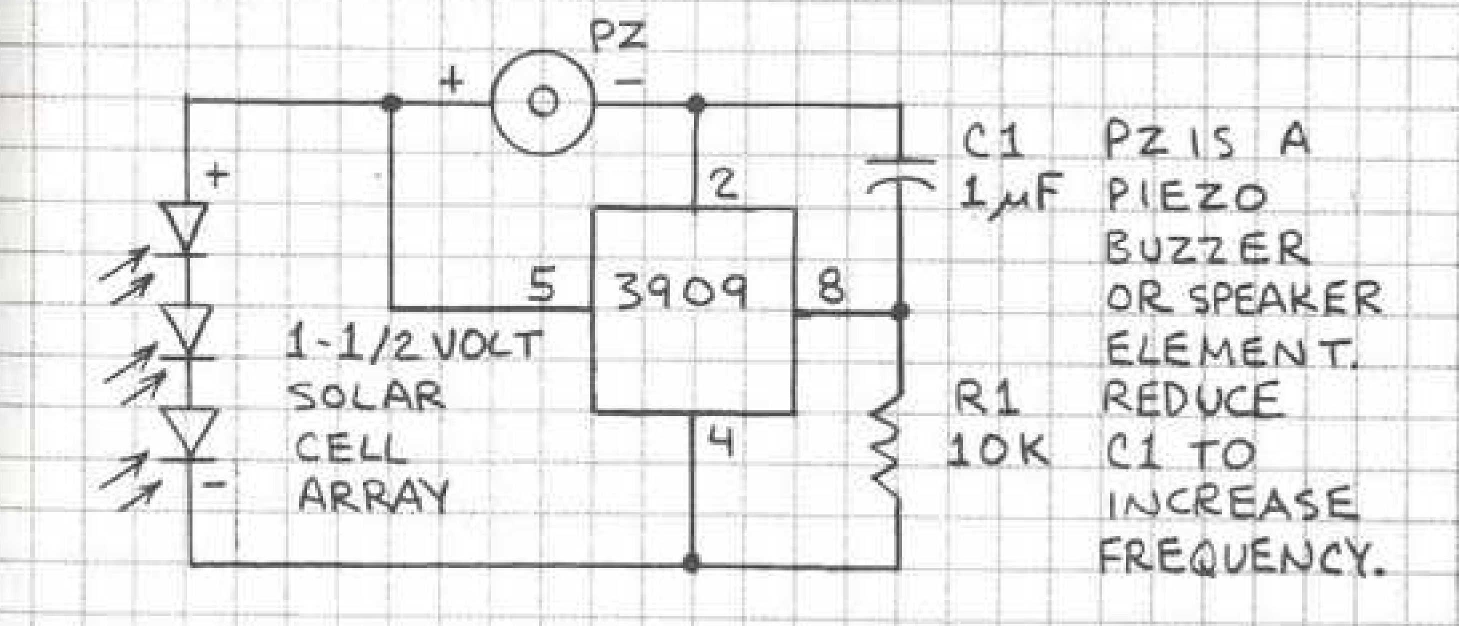


EXPERIMENT WITH VALUE OF C1 AND R1 TO CHANGE FREQUENCY.

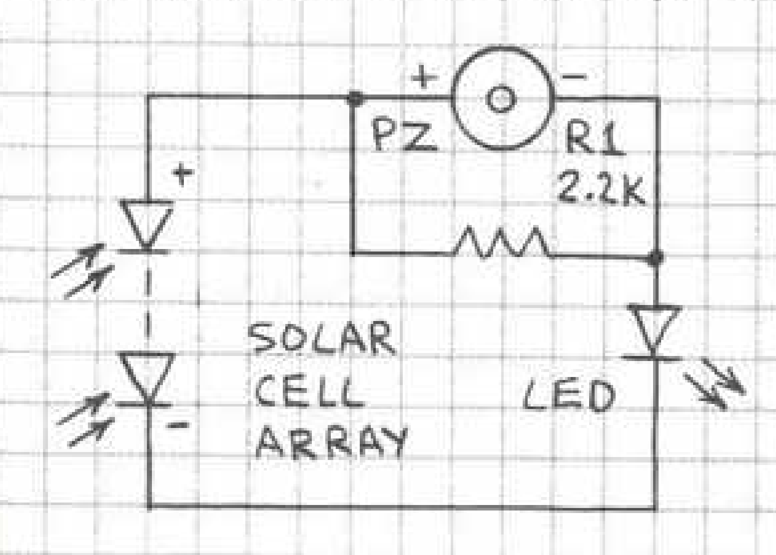
SOLAR POWERED 555 OSCILLATOR



SOLAR POWERED CLICKER (1)



SOLAR POWERED CLICKER (2)



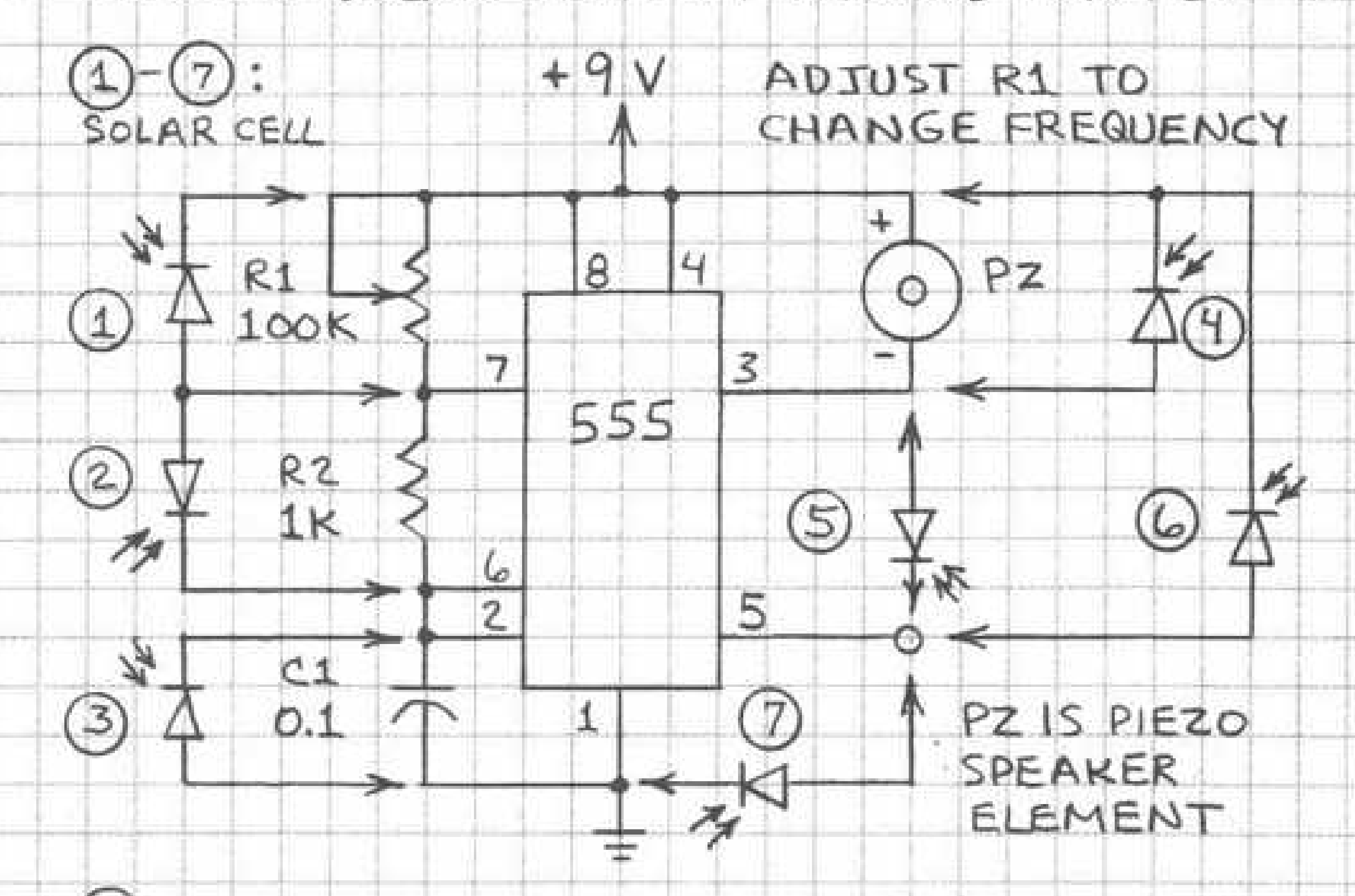
THIS CIRCUIT EMITS SOUND LIKE THAT OF A TICKING CLOCK. USE 3-VOLT SOLAR ARRAY. LED IS A BLINKING TYPE LED. OK TO REPLACE PZ WITH MAGNETIC SPEAKER.

LIGHT CONTROLLED TONE

SILICON SOLAR CELLS CAN BE USED IN MANY KINDS OF TONE GENERATORS THAT RESPOND TO DAYLIGHT OR ARTIFICIAL LIGHT.

LIGHT CONTROLLED 555 OSCILLATOR

THE FREQUENCY AND VOLUME OF SOUND PRODUCED BY A BASIC 555 OSCILLATOR CAN BE EASILY MODIFIED BY CONNECTING A SILICON SOLAR CELL AT VARIOUS POINTS.

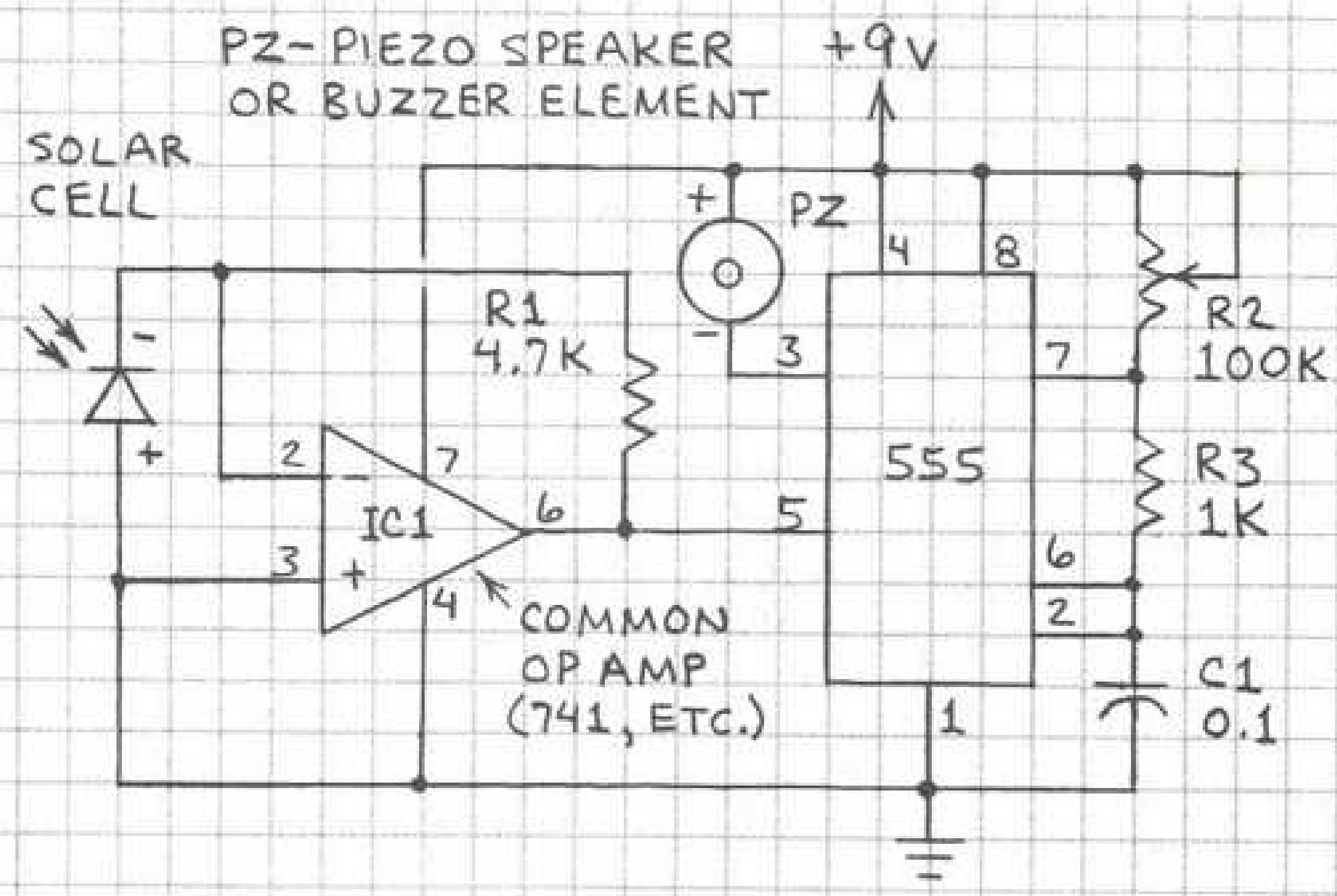


(1) CONNECT SOLAR CELL HERE. INCREASING LIGHT WILL INCREASE TONE FREQUENCY.
(2) WITH CELL CONNECTED HERE, INCREASING LIGHT REDUCES VOLUME FROM PZ.
(3) LIGHT FALLING ON CELL HERE REDUCES FREQUENCY OR CUTS OFF TONE ENTIRELY.
(4) LIGHT STRIKING CELL HERE REDUCES VOLUME FROM PZ OR CUTS OFF TONE.
(5) LIGHT FALLING ON CELL HERE CUTS OFF TONE OR CAUSES CHIRPS.
(6) LIGHT STRIKING CELL HERE REDUCES THE TONE FREQUENCY.

(7) WITH CELL HERE, INCREASING LIGHT INCREASES TONE FREQUENCY.

AN INTERESTING APPLICATION IS TO REPLACE C1 WITH A SOLAR CELL. SINCE A SOLAR CELL HAS CAPACITANCE, THE CIRCUIT WILL OSCILLATE. LIGHT AT THE CELL WILL CHANGE THE TONE FREQUENCY OR CUT IT OFF ENTIRELY. THE CELL SHOULD BE ORIENTED LIKE CELL (3).

HIGH GAIN LIGHT CONTROLLED TONE

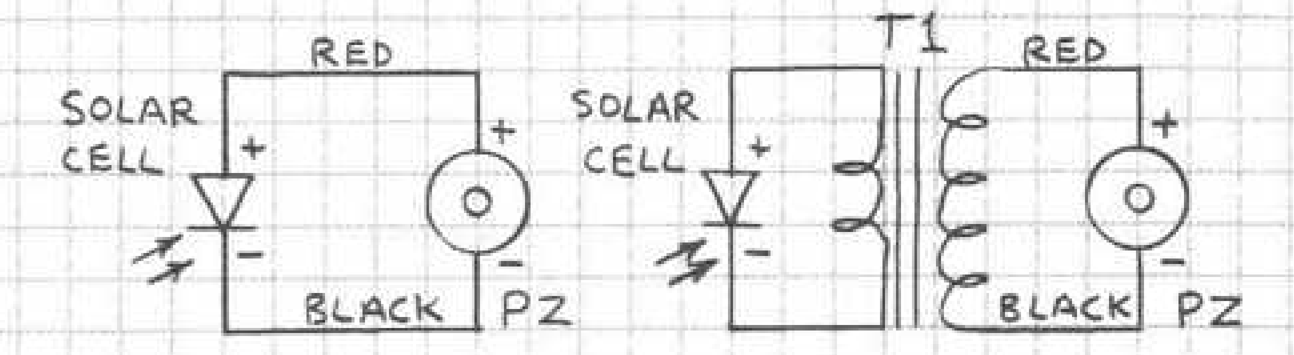


THE FREQUENCY OF THE TONE PRODUCED BY THIS CIRCUIT IS REDUCED AS THE INTENSITY OF LIGHT AT THE SOLAR CELL IS INCREASED. IN OPERATION, THE PHOTOCURRENT FROM THE SOLAR CELL IS AMPLIFIED AND CONVERTED TO A VOLTAGE BY OP AMP IC1. THIS VOLTAGE IS THEN APPLIED TO THE CONTROL INPUT OF A 555 IC CONNECTED AS AN OSCILLATOR. WHEN THE SOLAR CELL IS DARK, ADJUST R2 UNTIL THE DESIRED TONE IS PRODUCED. THEN ILLUMINATE THE SOLAR CELL. YOU CAN GET UNIQUE EFFECTS BY USING A FLASHING LIGHT.

IR REMOTE CONTROL TESTERS

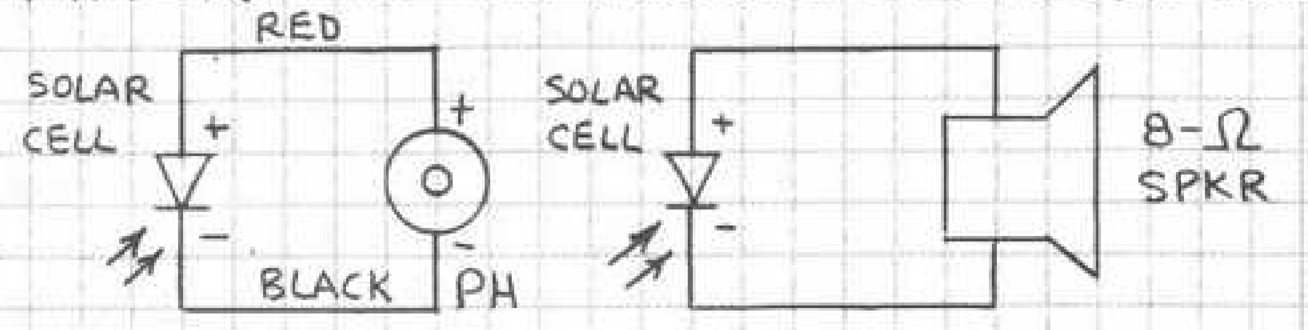
NEAR-INFRARED EMITTING DIODES ARE USED IN REMOTE CONTROL TRANSMITTERS FOR TELEVISIONS, VIDEO RECORDERS AND OTHER SYSTEMS. THEY ARE ALSO USED TO TRANSMIT DATA FROM VARIOUS COMPUTERS. THE CIRCUITS SHOWN HERE VERIFY THAT NEAR-INFRARED TRANSMITTERS ARE OPERATING.

PIEZO ELEMENT TESTERS



PZ IS ANY PIEZOELECTRIC SPEAKER ELEMENT OR EARPHONE. (DO NOT USE A PIEZOELECTRIC BUZZER.) T1 IN THE CIRCUIT ON THE RIGHT IS ANY MINIATURE AUDIO OUTPUT TRANSFORMER. THIS CIRCUIT PROVIDES A LOUDER SOUND THAN THE CIRCUIT ON THE LEFT. TEST THE IR REMOTE CONTROL TRANSMITTER BY POINTING IT AT THE SOLAR CELL. A TONE WILL BE HEARD IF THE UNIT IS WORKING.

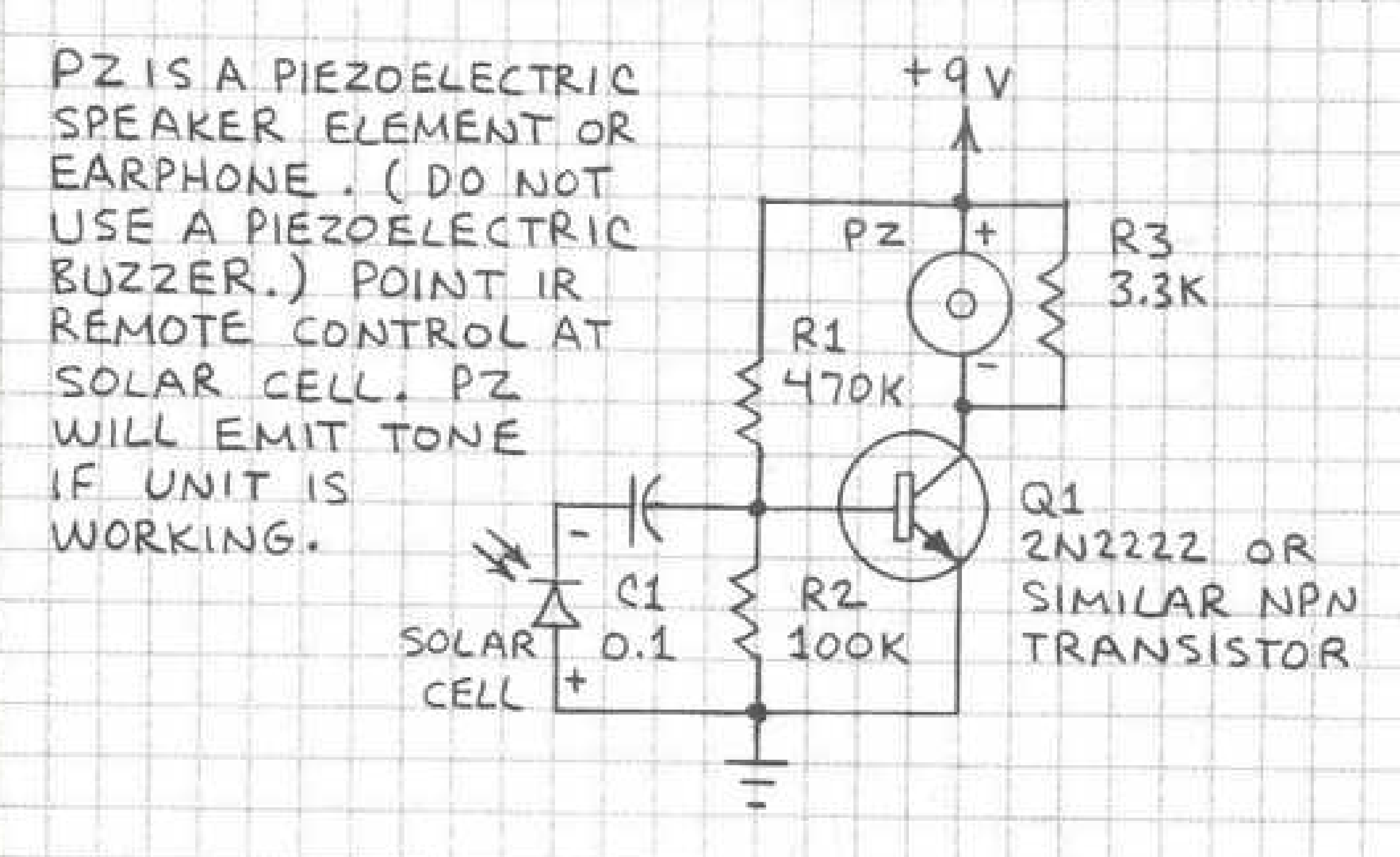
MAGNETIC TRANSDUCER TESTERS



PH IS A MINIATURE MAGNETIC EARPHONE. BOTH CIRCUITS EMIT A TONE WHEN A WORKING IR TRANSMITTER IS POINTED AT THE SOLAR CELL. USE A SOLAR ARRAY FOR MORE VOLUME.

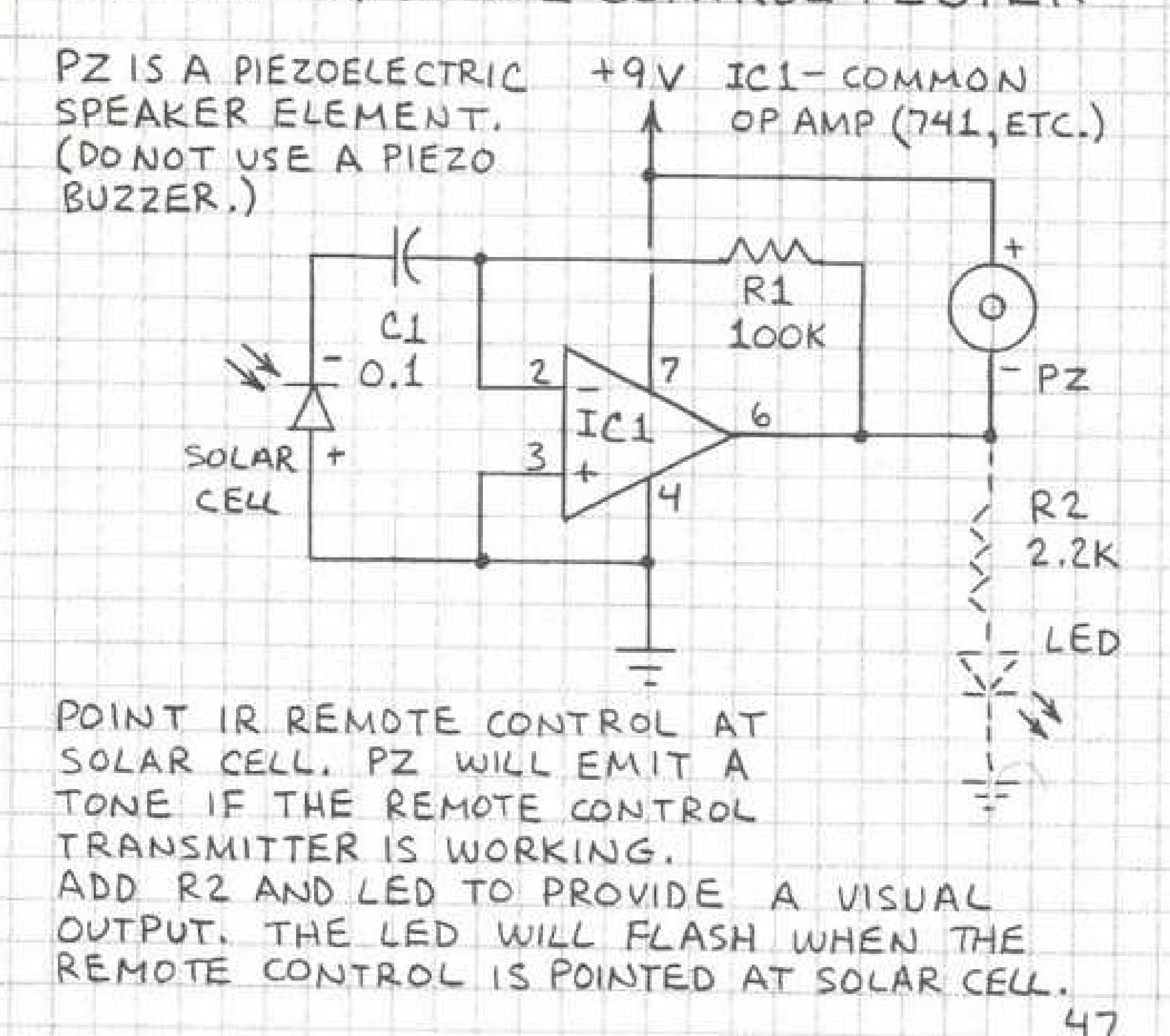
TRANSISTOR REMOTE CONTROL TESTER

PZ IS A PIEZOELECTRIC SPEAKER ELEMENT OR EARPHONE. (DO NOT USE A PIEZOELECTRIC BUZZER.) POINT IR REMOTE CONTROL AT SOLAR CELL. PZ WILL EMIT TONE IF UNIT IS WORKING.



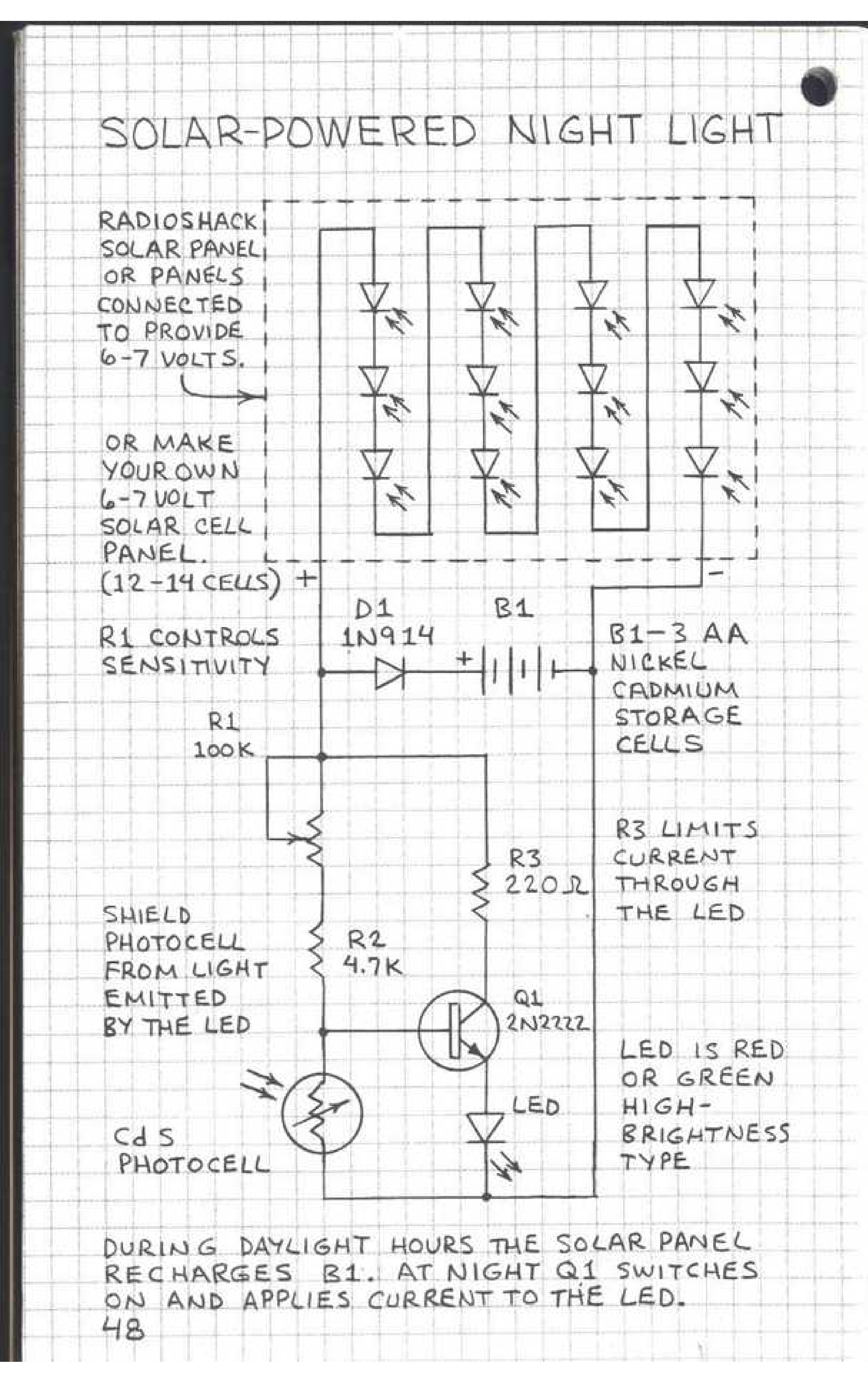
OP AMP REMOTE CONTROL TESTER

PZ IS A PIEZOELECTRIC SPEAKER ELEMENT. (DO NOT USE A PIEZO BUZZER.)



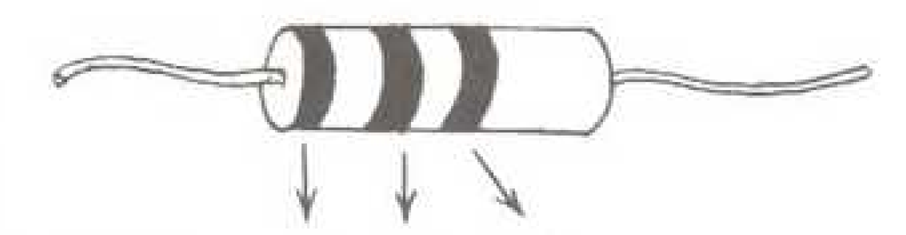
POINT IR REMOTE CONTROL AT SOLAR CELL. PZ WILL EMIT A TONE IF THE REMOTE CONTROL TRANSMITTER IS WORKING.
ADD R2 AND LED TO PROVIDE A VISUAL OUTPUT. THE LED WILL FLASH WHEN THE REMOTE CONTROL IS POINTED AT SOLAR CELL.

SOLAR-POWERED NIGHT LIGHT



DURING DAYLIGHT HOURS THE SOLAR PANEL RECHARGES B1. AT NIGHT Q1 SWITCHES ON AND APPLIES CURRENT TO THE LED.

RESISTOR COLOR CODE



BLACK	0	0	× 1
BROWN	1	1	× 10
RED	2	2	× 100
ORANGE	3	3	× 1,000
YELLOW	4	4	× 10,000
GREEN	5	5	× 100,000
BLUE	6	6	× 1,000,000
VIOLET	7	7	× 10,000,000
GRAY	8	8	× 100,000,000
WHITE	9	9	—

FOURTH BAND INDICATES TOLERANCE (ACCURACY):
GOLD = ± 5 %   SILVER = ± 10 %   NONE = ± 20 %

OHM'S LAW:

$V = IR$ $R = V/I$
$I = V/R$ $P = VI = I^2R$

ABBREVIATIONS

A = AMPERE	R = RESISTANCE
F = FARAD	V (OR E) = VOLT
I = CURRENT	W = WATT
P = POWER	Ω = OHM

M (MEG-)	=	× 1,000,000
K (KILO-)	=	× 1,000
m (MILLI-)	=	.001
μ (MICRO-)	=	.000 001
n (NANO-)	=	.000 000 001
p (PICO-)	=	.000 000 000 001